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HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
U S ARMY

TECHNICAL REPORT
EP-97

Canal Zone Analogs VI

ANALOGS OF CANAL ZONE CLIMATE IN SOUTH AMERICA

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION
NATICK, MASSACHUSETTS

SEPTEMBER 1958

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

Major General Andrew T. McNamara
The Quartermaster General
Washington 25, D.C.

Dear General McNamara:

This report, "Analogs of Canal Zone Climate in South America," is the sixth of a series of studies comparing the climates of tropical areas throughout the world with the climate of the Canal Zone.

The report presents information for military planners and test personnel on the extent to which the climates of Balboa Heights and Cristobal in the Canal Zone resemble those of South America. Thus it suggests the applicability to other regions of the results of clothing and equipment tests conducted in the Canal Zone.

Sincerely yours,

C. G. Calloway

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EP-97

C. G. CALLOWAY
Major General, USA
Commanding

HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-97

Canal Zone Analogs VI

ANALOGS OF CANAL ZONE CLIMATE IN SOUTH AMERICA

Will F. Thompson
Geographer

Regional Environments Research Branch

Prepared for the Environmental Analogs Project (8-97-10-004)
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FOREWORD

A successful research, development, or training program requires knowledge of the extent of environmental representativeness of test sites and training areas. The Quartermaster Corps, at the request of the Corps of Engineers, Waterways Experiment Station, under a directive from the U. S. Army General Staff, is developing a generalized, comparative, climatic picture of the wet tropics throughout the world by a series of tropical analog studies. The series parallels two other completed series which presented comparisons between (1) Yuma Test Station and other desert regions of the Northern Hemisphere, and (2) Fort Greely, Alaska, and Fort Churchill, Canada, and other arctic and subarctic regions.

This is the sixth report of the tropical series. It compares the Canal Zone climate with that of South America and, by so doing, provides a climatic reference for military planners and test personnel.

AUSTIN HENSCHEL, Ph.D.
Chief
Environmental Protection Research Division

Approved:

CARL L. WHITNEY, Lt. Colonel, QMC
Commanding Officer
QM R and E Center Laboratories

A. STUART HUNTER, Ph.D.
Scientific Director
QM Research & Engineering Command

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ABSTRACT

Much of interior and eastern South America is climatically similar to the Canal Zone. Lowlands on the west coast north of Guayaquil are also similar, except that over considerable areas they have much more precipitation than any part of the Canal Zone. Highlands throughout the area mapped in this study are too cool for close analogy; subtropical areas in the southern part of the area are too cool in winter. The coast of Venezuela, the northern Brazilian Plateau, northwest Argentina, and the west coast south of Guayaquil are much too dry for climatic analogy with the Canal Zone.

Tropical lowlands considered analogous to Balboa Heights, on the drier, Pacific side of the Canal Zone, have only moderately heavy precipitation and a well-marked dry season. Such areas are about twice as widespread in the study area as those analogous to Cristobal, the other Canal Zone station, which is on the wetter, Atlantic side. Cristobal has heavy precipitation, though much less than the maximum amounts recorded in tropical South America, and has a brief dry season. Certain areas otherwise climatically similar to Cristobal fail of complete analogy because they have no dry season. For example, this is true of much of the northern part of the Amazon Basin.

ANALOGS OF CANAL ZONE CLIMATE IN SOUTH AMERICA

1. Purpose and scope

This report is the sixth of a series comparing the climate of Cristobal and Balboa Heights, Canal Zone, with other tropical regions of the world. These two stations were selected to represent respectively the climates of the Atlantic and Pacific portions of the Canal Zone. The environment of Cristobal is described in a previous report (Wiley and others, 1955).

No attempt has been made to provide a regional climatology of South America. Instead, the method has been to select certain climatic elements that are considered particularly significant and, for each of these, to map the areas within the region considered closely analogous to either Balboa Heights or Cristobal. Some of the information presented on these maps of single climatic elements has been consolidated into two composite maps, one for each of the two Canal Zone stations, showing areas where there is a coincidence of analogy for two to four climatic elements.

2. Delimitation and geography of South America

This study covers all of tropical South America and extends into the southern subtropics. The area south of 28°S has been omitted.

a. Topography

The great climatic contrasts of the South American tropics and subtropics are due in part to relief. The regional topographic breakdown given below will aid in the description of the climatic distributions mapped in this study (Fig. 2).

The Pacific coast ranges and coastal plain constitute a narrow zone which follows the western margin of the study area for almost its whole length. This zone has considerable relief, though much less than the adjacent Andes, and is less than 100 miles wide. South of the Gulf of Guayaquil, the coast is desert and the piedmont plains of the Andes lie as high as 3,000 feet above the sea. Undissected stretches have many undrained depressions behind a low, barren coastal range.

North of Guayaquil, the average level of the piedmont declines. In Colombia the piedmont is densely forested, traversed by many moderately large rivers with gradients low enough for canoe navigation, and fringed to seaward in many places by mangrove swamps. Even in the north, however, there are low ranges along part of the immediate coast.

The Andes form an effective climatic barrier which parallels the Pacific coast of the continent throughout its length. Elevations of more than 10,000 feet are maintained for almost the whole length of the tropical and subtropical parts of the range. In the southern part of the study area there is a plateau more than 200 miles wide at its widest part, and roughly 12,000 feet in elevation, which is enclosed on both sides by ranges 18,000 to 20,000 feet high. In southern Bolivia the width of the whole range, including the plateau, is about 400 miles.

At the northern end of the high plateau in central Peru, the range narrows sharply to a width of 200 miles or less, but retains its height for several hundred miles northward. In northernmost Peru and in Ecuador, however, there are several passes as low as 7,000 feet in height. In southern Colombia, the range is divided into three parallel chains separated by deep longitudinal tropical valleys which, for most of their length, drain into the Caribbean. There are also several passes through the range in Colombia, but the general height of the central and western ranges is more than 10,000 feet. Most of their summits rise much higher; the highest, Chimborazo, in Ecuador, is 20,702 feet. The two western ranges end, except for a few low spurs, about a hundred miles south of the Caribbean coast. At the same latitude, approximately 7°N, the eastern range branches. One fork extends north and ends in the great Sierra Nevada de Santa Marta which rises 19,000 feet directly from the Caribbean shore. The other fork extends eastward, south of Lake Maracaibo, and follows the Venezuelan coast. It is relatively narrow and discontinuous, and declines in height from west to east, continuing seaward from Trinidad as the Caribbean island arc.

A "basin and range" province topographically somewhat like that of North America, but smaller, occurs on the eastern flank of the Andes at the southern margin of the study area in northwest Argentina. Its undrained desert basins, separated by barren spurs of the Andes, occur at various elevations. The highest ones have landscapes transitional to those of the even higher undrained basins on the Bolivian Plateau to the north.

The Caribbean Coast and Guiana Coast lowland includes: (1) several low-lying plains at the mouths of the Atrato, Magdalena, and other rivers along the Colombia coast east of the Isthmus of Panama, (2) the Maracaibo Basin, (3) the Orinoco Delta, and (4) the low coastal plains of Guiana. The Guiana coast lowland, more than 100 miles wide at most points, is traversed by many rivers, all running at moderate or low gradients directly from the interior highlands to the sea.

A belt of great fluvial plains east of the Andes in the interior of the continent includes (1) the Orinoco Lowlands or Llanos, (2) the Amazon Basin, and (3) the Parana-Paraguay Lowland. The Llanos lie south of the Venezuelan coast range and northwest of the Orinoco River and the Guiana Highland. The huge Amazon Basin occupies the whole center of the continent and extends eastward to the Atlantic as a corridor separating

the two eastern highland regions (Guiana Highland and Brazilian Highland) discussed below. The broad Paraná-Paraguay lowland, which includes the seasonally flooded Gran Chaco, lies at the southern margin of the study area between the Andes (including the "basin and range province"), and the southern Brazilian Highland.

The Guiana Highland, divided into eastern and western parts, is the smaller northern section of the eastern highlands of South America. The western part occupies Venezuela southeast of the Orinoco, and extends into British Guiana and Brazil. It is mountainous, with characteristically flat-topped, cliff-encircled summits up to 9,000 feet. The eastern part, between the Guianas and the lower Amazon, is almost entirely below 3,000 feet and is separated from the western part by lowland corridors which meet at a low pass.

The Brazilian Highland, a much larger region, is south of the Amazon and about as large as the Amazon Basin. It is a broadly rolling plateau mostly below 4,000 feet, continuously steep only along its Atlantic scarp below 20°S (the Serra do Mar). Various parts of the upland are separated from one another by deep, broad valleys. Several of the longest valleys, including the great São Francisco valley, radiate in various directions from an area in the heart of the range about 300 miles inland from Rio de Janeiro.

b. Major climatic controls

The region discussed in this report is tropical except along its southern part, which is subtropical. Over most of the region the major climatic control is a system involving the Northeast and Southeast Trade Winds from the Atlantic, and a zone of rainfall known as the equatorial trough of barometric pressure. As in other tropical regions, this equatorial trough tends to follow the northward and southward shift of the sun within the limits of the tropics. In South America, the equatorial trough does not move as far north or south as the sun does. The migration southward of the equatorial trough is poorly developed and never moves far enough south to draw the Northeast Trade Winds across the Equator. In the Pacific, near the coast of Colombia, the Southeast Trade Winds are drawn into the Northern Hemisphere during the northern summer; east of the Andes, in the Atlantic, they apparently are not.

Ideally, the seasonal shift of the equatorial trough results in two periods of maximum rainfall at a point in the central tropics (Table VI). At the northern and southern limits of the migration of the equatorial trough, the tendency to have two rainfall maxima disappears and there is only a single wet season, and the dry season usually grows longer. In much of the southern part of the study area east of the Andes, summer rain is associated with a region of low pressure which develops over southern interior Brazil, independent of the equatorial trough. On the Pacific coast, the influence of the equatorial trough is not ordinarily felt south

of Guayaquil though, in exceptional years, the rainy zone follows an abnormal extension of the equatorial counter-current, El Niño, far down the desert coast of Peru.

Within the tropics, topography, other local controls, and irregularities in the general circulation produce strong climatic contrasts. Thus, parts of the desert coast of Chile and southern Peru have been without rain for years because they lie between the high Andes and upwelling cold Pacific water. Along the dry coast of Venezuela, also backed by mountains there is upwelling of cool water. Furthermore, the Trade Winds blow parallel to the coast rather than toward it. The great drought region of northeast Brazil lies south of the range of the equatorial trough and its coastal mountains keep moisture from being brought to it by the Trade Winds.

The interior Andean plateau in Bolivia and Peru also receives scant precipitation because it is in the lee of mountains on the west which are many thousands of feet higher in elevation. Heavy precipitation occurs on the windward side of many of the mountains, but often seems to be even more intense out over the lowlands windward of the range, as in the Amazon Basin or on the Pacific coast of Colombia.

Some winter cooling of the air occurs along the southern part of the study area. Otherwise, temperatures over the whole area are determined mostly by altitude. Daily temperature ranges tend to be considerably greater than annual temperature ranges. In many places on the immediate coast, onshore trade winds or sea breezes minimize even daily temperature ranges. Daily ranges are also moderate in the Amazon Basin because of its long rainy season.

3. Climatic Summary of the Canal Zone

The Pacific portion of the Canal Zone, represented by Balboa Heights, has a moderately humid, tropical climate with a relatively dry season of four months (Fig. 1). The difference in mean monthly temperatures of the warmest and coldest months is only 2F°, and the range from the highest mean daily maximum (March and April, 90°F) to the lowest mean daily minimum (February, 71°F) is only 19F°. The mean annual temperature of 79°F is typical of equatorial areas. Precipitation, averaging 70 inches annually, is markedly seasonal. Two months, February and March, have less than 1 inch of rainfall, and 5 months have more than 8 inches. The dry season begins in December and ends in April. Rainfall during the remaining months is more than 7 inches; October and November both have more than 10 inches. Relative humidity is high from June through November. Cloudiness is at a maximum from May through November, coinciding with the wet season; sky coverage averages about 8 tenths at Balboa Heights at that season. Wind speed, however, is greatest during the dry season; winds average 9 to 10 mph at Balboa Heights from January through April, but only about 5 to 6 mph in the other months. Southeastward toward the coast, there is a

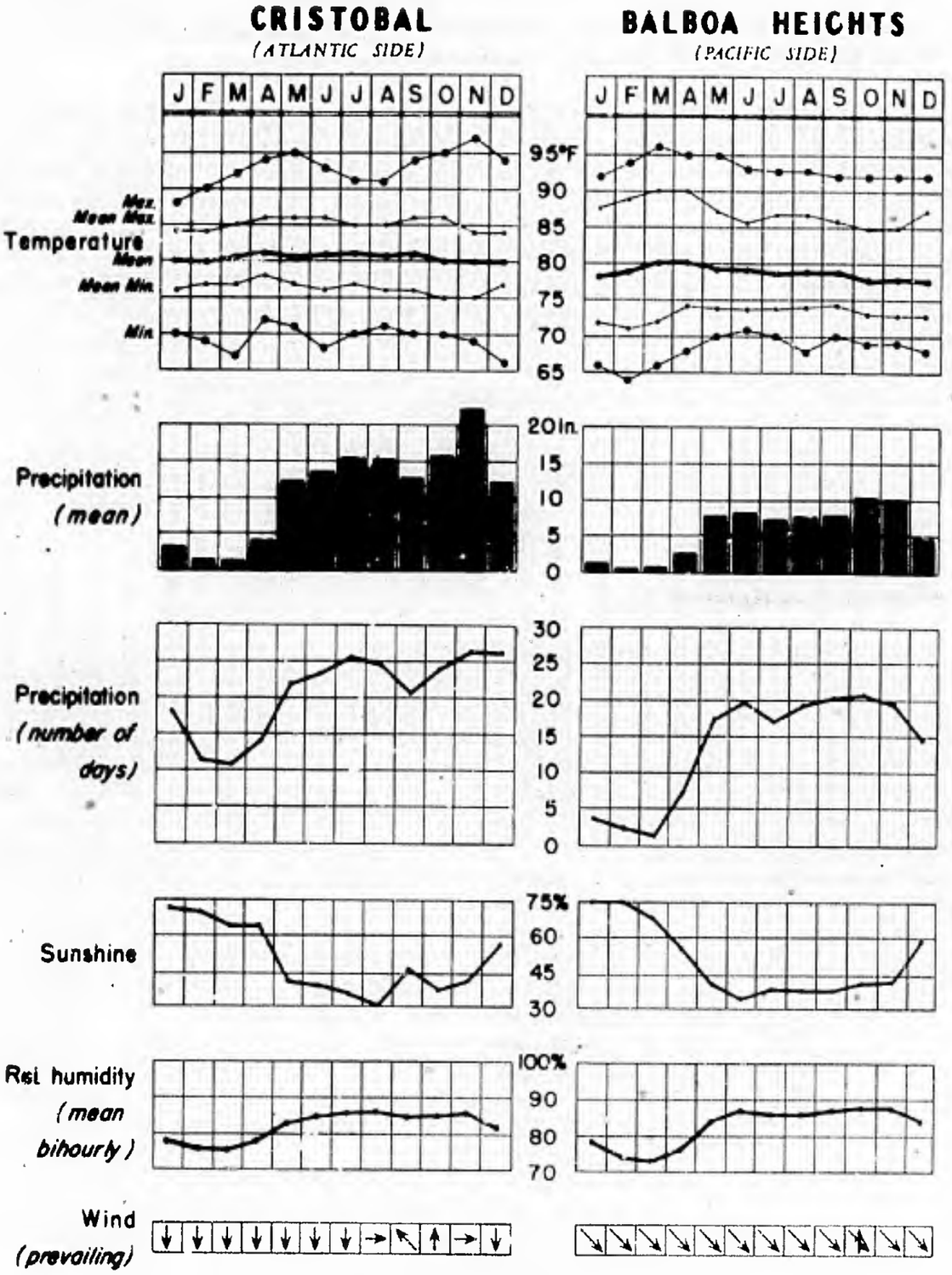

Figure 1. Climatic Summary of 2 Canal Zone stations

slight decrease in rainfall and an increase in temperature, as elevation drops to sea level from 118 feet at Balboa Heights.

The Atlantic portion of the Canal Zone, represented by Cristobal, has a wet-tropical climate (Fig. 1). The difference in mean temperatures of the warmest and coolest months is only 2F°, and the range from the highest mean daily maximum (April, May, June, September, and October, 86°F) to the lowest mean daily minimum (October and November, 75°F) is only 11F°. The mean annual temperature of 81°F is typical of equatorial areas. Precipitation averages 130 inches a year, and the monthly distribution is uneven. Although no month can be considered completely dry, 2 months have less than 2 inches of rainfall, while 8 months have more than 11 inches. The "dry" season at Cristobal begins in January (3.4 inches) and ends in April (4.1 inches). During the remaining months, average rainfall ranges from nearly 12, to more than 22 inches in November. Mean relative humidity is high in all months; the lowest mean value, 77 percent, occurs in both February and March. Cloud cover is greatest in July, 8 tenths, and least in February, 5.5 tenths. Mean wind speed is greatest in February and March (nearly 15 mph) and least in September (about 6 mph).

4. Criteria and methods

a. Climatic elements selected for study

As in the previous studies of this series, temperature, precipitation, humidity, cloud cover, and wind speed were the climatic elements considered most important to military activities. It was assumed that test authorities are more interested in stress periods (e.g., hottest and wettest) and annual fluctuations than in the data for specific calendar months. Accordingly, the warmest, coldest, wettest, and driest months of the year at each station were selected for study. The following specific combinations of element and month were studied:

(1) Mean temperature of the warmest month
(2) Mean daily maximum temperature of the warmest month
(3) Mean temperature of the coldest month
(4) Mean daily minimum temperature of the coldest month
(5) Mean daily temperature range of the warmest month
(6) Mean annual precipitation
(7) Mean precipitation of the wettest month
(8) Number of wet months
(9) Relative humidity of the driest month
(10) Mean cloud cover of the wettest month
(11) Mean wind speed of the wettest month

b. "Analogous" and "semianalogous" ranges defined

Classes were established defining the ranges of values considered closely analogous to those for Balboa Heights and Cristobal. Fairly narrow limits of analogy were used to keep comparisons closely representative of the two reference stations. Table I lists the classes of analogy

and semianalogy selected for each element. For temperature, a departure of 4 degrees (except where a mean was taken for the two reference stations) from the mean at the Canal Zone station was allowed for each analogy class, and an additional 4 degrees for semianalogy. For precipitation, departures of 15 inches of mean annual rainfall were considered analogous to Balboa Heights and an additional 15 inches for semianalogy. The mean annual rainfall of 70 inches at Balboa Heights is somewhat below that normally considered humid equatorial for a locality with a dry season; therefore, in this study the limits of analogy were set at 55 to 85 inches, differentiating it from most evergreen rain forest areas, on the upper margin, and savanna areas, on the lower margin. Cristobal, which has a tropical evergreen rain forest type of climate, has a mean annual rainfall of 130 inches. Departures of 30 inches of mean annual rainfall were considered analogous to Cristobal and an additional 30 inches was considered semianalogous. Departures of 5 percent in mean relative humidity, 1 tenth in amount of cloudiness, and 2 mph in wind speed were selected as ranges of analogy for these respective elements.

c. Explanation of maps

Values are shown for each station, with degree of analogy indicated by a symbol. Isopleths were drawn to show zones of close analogy, and these zones are shaded. Areas of semianalogy were not shaded but were indicated by placing the appropriate symbol on the map for stations having semianalogous conditions. From the separate maps showing analogous areas for each element, two composite maps were prepared (one for Balboa Heights and one for Cristobal) indicating regions where the following four single elements are analogous: mean temperature of the warmest month, mean temperature of the coldest month, mean annual precipitation, and number of wet months.

d. Limitations of data

The procedures as outlined have certain definite limitations in a climatic comparison of this sort. Foremost among these is the necessity, often encountered in climatology, of assuming climatic conditions in areas having few if any stations. A second limitation is that some elements, such as dew point, solar radiation, and visibility, which would have proved valuable as indicators of climatic analogy, were not included in this study because of the limited amount of data available. For certain elements, the number of stations reporting does not provide a representative picture. Consequently, isopleths were not drawn for the following: mean relative humidity for the driest month, mean cloudiness for the wettest month, or mean wind speed for the wettest month.

The assumption has been made that Balboa Heights and Cristobal are representative of the Pacific and Atlantic portions of the Canal Zone.

Data of some S. American stations are not given in a form directly comparable to those from Balboa Heights and Cristobal. Where periods of record, hours of observation, or manner of observation differed, station records had to be interpolated in drawing the isopleths.

Values outside the limits of analogy or semianalogy were not analyzed, nor were combinations of climatic elements other than those involved in computing number of wet months.

The method of recording temperatures varies from country to country. Mean temperatures are usually determined by averaging the daily maximum and minimum temperature; however, at some stations in South America the means are obtained by averaging bi-hourly temperature observations, as at Balboa Heights and Cristobal. Experience has shown that the difference between mean temperatures derived in these different ways is seldom more than 1F°. Hours of observation of relative humidity, wind speed, and cloudiness vary widely throughout the study area.

5. Analysis of single-element maps

Individual maps showing analogous areas have been prepared for the climatic elements listed in paragraph 4a above, numbers 1 through 8. Maps of elements 9, 10, and 11 have been prepared showing only the values for individual stations, since the data were considered inadequate for delimiting analogous areas.

a. Mean temperature, warmest month (Fig.3)

As Table I indicates, Balboa Heights and Cristobal have almost the same mean temperature for the warmest month, 80° and 82°F. respectively. The map therefore shows only one 8F° zone of analogy, lying between the 77° and 85°F. isotherms. On this map, all lowlands except the deserts of the Pacific Coast south of Guayaquil are analogous; no mountains or major highlands are analogous.

b. Mean daily maximum temperature, warmest month (Fig. 4)

At Balboa Heights, the mean daily maximum temperature for the warmest month is 90°F, whereas at Cristobal, which has a shorter and less pronounced dry season, it is 86°F. Analogous areas are those which have temperatures within 4F° of these means. The 82° to 90°F range is analogous to Cristobal, the 86° to 94°F range to Balboa Heights; the 86° to 90°F range is analogous to both. Conditions either analogous to or hotter than those at Balboa Heights are very extensive, covering an area similar to that of "combined" analogy (i.e., analogous to both Canal Zone stations) in Figure 3. Temperatures too high for analogy appear at only one dry subtropical station near the base of the Andes in Argentina. Semianalogy (in the hotter ranges) is extensive, not only in that area but also on the interior side of the northern Brazilian Highland and around the base of the eastern Guiana Highlands. Small areas of hot semianalogy appear in the São Francisco Valley and on the Venezuelan Llanos. In the highlands and along the coasts, vertical zonation belts of combined analogy, Cristobal analogy, cool semianalogy, and cool nonanalogy are found in sequence. The highest parts of the Serra do Mar are semianalogous.

c. Mean temperature, coldest month (Fig. 5)

Balboa Heights and Cristobal have nearly the same mean temperatures in their coldest month, 78°F and 80°F respectively, just as they do in their warmest month (80°, 82°F, respectively). For simplicity, a single 8F° zone of analogy centered on a mean of 79°F (75° to 83°F), is presented. Analogy is confined to the tropics and to areas of slight altitude.

d. Mean daily minimum temperature, coldest month (Fig. 6)

At Balboa Heights, the mean daily minimum temperature of the coldest month is 71°F; at Cristobal, 75°F. The 4F° range of analogy used on both sides of each of these means extends analogy with Balboa Heights to 67°F; with Cristobal to 79°F. Stations with temperatures between 71°F and 75°F are analogous to both Canal Zone stations. No area is analogous to Cristobal alone. The total area of Balboa Heights analogy and combined analogy have much the same distribution as the area of combined analogy on Figure 5. Balboa Heights analogy is extensive only over the northwestern Amazon Basin and the Guiana Highlands. Elsewhere it occurs only as a transition zone following the cool margin of the area of combined analogy.

e. Mean daily temperature range, warmest month (Fig. 7)

At Balboa Heights, the mean daily range of temperature in the warmest month is 16F°. At Cristobal, with onshore marine winds, the daily range is only 8F°. A range of 4F° on either side of these means is considered analogous. The 12F° isotherm therefore separates the two zones of analogy. Balboa Heights analogy is dominant on Figure 7. Cristobal analogy is confined to narrow strips along the coast and a few isolated spots in the mountains which are high summits or particularly cloudy locations. No areas have a range too small for analogy with Cristobal. Areas having a range too great for Balboa Heights analogy include the following: (1) nearly all of the northern and interior parts of the Brazilian Highlands, (2) the eastern Guiana Highlands, (3) plateau areas and dry sheltered valleys in the Andes, and (4) a large subtropical area stretching across the southern margin of the study area from the Serra do Mar almost to the Pacific coast. A narrow and discontinuous zone, nonanalogous because of excessive temperature range, follows the desert piedmont at the western base of the Andes. This zone lies between the immediate coast and the adjacent Andean scarp, both of which are usually analogous to Balboa Heights.

f. Mean annual precipitation (Fig. 8)

At Balboa Heights, the mean annual precipitation is 70 inches, at Cristobal, 130 inches. A 30-inch range on either side of the mean is considered analogous to Cristobal, a 15-inch range for Balboa Heights. The only areas in South America too rainy for analogy with Cristobal are the Pacific coast of Colombia and a few small areas on the east side of the

Andes facing the upper Amazon Basin. The largest area of analogy with Cristobal covers the Guiana Highlands and upper Orinoco and Amazon Basins extending south along the eastern front of the Andes. Another zone of Cristobal analogy borders the region of heavy rainfall on the Pacific coast of Colombia and follows the mountain front northward to the western side of the Santa Marta Range. A zone of Cristobal analogy also occurs at the mouth of the Amazon and extends north into French Guiana; still another occurs south of the middle course of the Amazon. Small areas of such analalogy also occur on the crest of the Serra do Mar near Rio de Janeiro and on the Guiana Coast.

Balboa Heights analogy is very extensive in South America because much of its tropical area is transitional between the very wet and dry conditions. Large areas too dry for analogy occur in parts of the Brazilian Highlands, on the desert coast south of Guayaquil, on the east side and plateaus of the Andes, in the Paraguay River watershed, and on the southwestern margin of the upper Amazon Basin.

g. Mean precipitation, wettest month (Fig. 9)

The mean precipitation of the wettest month is 11 inches for Balboa Heights and 22 inches for Cristobal. Analogy for Balboa Heights is between 8 and 14 inches; for Cristobal, between 15 and 29 inches. Most of the study area is analogous to one or the other of the two Canal Zone stations. Many areas are too dry for analogy. The only area too wet for analogy is the Pacific coast of Colombia. Broad areas of Cristobal analogy are found at the mouth and south of the Amazon, in the upper Amazon Basin, along the eastern slopes of the Andes, and in the Guiana Highlands. Cristobal analogy also borders the wet region of the Pacific coast of Colombia and extends north into the Isthmus of Panama. Also, small areas of Cristobal analogy are found on the Brazilian Highland and at the northern base of the Columbian Andes. The remaining areas lying between areas of Cristobal analogy and the dry areas are analogous to Balboa Heights.

h. Number of wet months (Fig. 10)

In this series of analogs, the term "wet month" is based on the Thornthwaite (1931) formula. A month is considered wet if the monthly mean precipitation equals or exceeds the amount given by the table opposite its monthly mean temperature. An abbreviated version of the table is given below:

Mean Monthly temperature (°F)	Mean Monthly precipitation (in.)
95	2.88
90	2.71
85	2.54
80	2.37
75	2.20
70	2.03
68	1.96

Balboa Heights has an average of 9 wet months according to this formula; Cristobal has 10. Areas having a wet period one month longer or shorter than these means are considered analogous. A station with 8 wet months is thus analogous to Balboa Heights, one with 9 or 10 wet months is analogous to both Canal Zone stations, and one with 11 wet months is analogous to Cristobal. In Figure 10 extensive areas are too wet, having 12 wet months. Areas of Cristobal analogy are narrow zones bordering each of these regions. Balboa Heights analogy fringes those areas that are too dry and is very extensive in (1) the transition zone between the Brazilian Highland and the central Amazon Basin, (2) the western part of the Brazilian Highland and eastern part of the Guiana Highlands, (3) at the mouth of the Amazon, and (4) in the Llanos and the Maracaibo Basin of Venezuela.

i. Relative humidity, driest month (Fig. 11)

Relative humidities of the driest month of 70 to 80 percent and 72 to 82 percent are considered analogous for Balboa Heights and Cristobal respectively. No areas of analogy are mapped because of the sparsity of data and the difficulty of determining its comparability. The data shown indicate that analogy is very widely distributed.

j. Mean cloudiness, wettest month (Fig. 12)

Sky cover of 7 to 9.0 tenths is considered analogous for both Canal Zone stations in the wettest month. No areas of analogy are drawn because of sparsity of data, but inspection of the scattered stations shows that analogy is widespread.

k. Mean wind speed, wettest month (Fig. 13)

Wind speed analogy of Balboa Heights for the wettest month is 4 to 8 mph and that of Cristobal is 6 to 10 mph. No areas of analogy are drawn because of sparsity of data. Most coastal stations are analogous with one or the other of the Canal Zone stations. Interior stations shown are mostly non-analogous because of light winds.

6. Analysis of Composite maps (Fig. 14 and 15)

Two maps have been prepared which show composite analogous areas for Balboa Heights (Fig. 14) and Cristobal (Fig. 15). These composite elements consist of analogy of the following criteria for each Canal Zone station: the mean temperature of the warmest month, the mean temperature of the coldest month, and mean annual precipitation. Because of the importance of seasonality of precipitation in the tropics, areas which are analogous with respect to the number of wet months are shown, but only where they occur within areas analogous with respect to the other three elements. This is done because full presentation of a fourth element would make the maps difficult to read.

For the elements mentioned above, areas analogous to either Balboa Heights or Cristobal occupy most of the lowland area of South America east of the Andes and north of the Brazilian Highland. Balboa Heights analogy occupies (1) a broad region extending from the Guiana Highlands to the Brazilian Highland, (2) a narrower area on the southwest margin of the Amazon Basin, (3) a large central area in the Llanos to the Orinoco Delta across to the northwestern Guiana Highlands, and (4) smaller areas in northern Colombia. Cristobal analogy occupies nearly all the rest of the lowlands west of the Andes and north of the Brazilian Highlands. Most of that area fails to have 4-way analogy because it has 12 wet months. Analagous areas border the wet areas of the Pacific coast of Columbia to the Santa Marta Range, from the mouth of the Amazon north to French Guiana, south of the Amazon River, and in the upper Amazon Basin in eastern Peru.

7. Tables of monthly values

Tables II through IX show the monthly and yearly means of the climatic elements for 23 South American key stations as well as the two Canal Zone stations. These stations were selected for length of reliable record and representativeness.

In the tables, Sucre represents the Bolivian plateau, Lima the desert coast, Huancayo the plateau, Tingo Maria the "Montaña" or eastern slope, Pucallpa the Amazonian piedmont, Guayaquil the coast between the dry and wet areas, Ambato the Andean plateau, Andagoya the northern Pacific Lowland, Maracaibo its Basin, Merida the Andes south of it, Caracas the coastal range in the east, Cayenne the Guiana Coast, Dadanawa the Guiana Highlands, Belem the Amazon delta, Manaos the interior of the Amazon Basin, and Porto Velho the headwaters of the Amazon Basin.

The following stations are on the Brazilian Plateau and its immediate coast. Imperatriz represents the northern interior, Natal the tip of eastern Brazil, Rio de Janeiro the coast near the southern limit of the study area, Salvador the area between Rio de Janeiro and Natal, Belo Horizonte the highland interior, Morro do Chapeu the interior lowland, and Cuyaba an interior highland station.

TABLE I: CLIMATIC ELEMENTS AND CLASSES OF ANALOGY

Station index	Balboa Heights			Cristobal		
	Value at B.H. (mean)	Analogous (range)	Semianalogous (range)	Value at Cris. (mean)	Analogous (range)	Semianalogous (range)
TEMPERATURE (°F)						
Mean, warmest month*	80	77-85	73-76 86-89	82	77-85	73-76 86-89
Mean daily maximum, warmest month	90	86-94	82-85 95-98	86	82-90	78-81 91-94
Mean coldest month*	78	75-83	71-74 84-87	80	75-83	71-74 84-87
Mean daily minimum, coldest month	71	67-75	63-66 76-79	75	71-79	67-70 80-83
Mean daily range, warmest month	16	12-20	8-11 21-24	8	4-12	0-3 13-16
PRECIPITATION						
Mean annual (inches)	70	55-85	40-54 86-100	130	100-160	70-99 161-190
Mean, wettest month (inches)	11	8-14	5-7 15-17	22	15-29	8-14 30-36
Number of wet months	9	8-10	7 11	10	9-11	8 12
RELATIVE HUMIDITY (%)						
Mean, driest month	75	70-80	65-69 81-85	77	72-82	67-71 83-87
CLOUDINESS (tenths)						
Mean, wettest month	7.6	7.0-8.9	6.0-6.9 9.0-10.0	7.6	7.0-8.9	6.0-6.9 9.0-10.0
WIND SPEED (mph)						
Mean, wettest month	5.8	4-8	2-3 9-10	8	6-10	4-5 11-12

*See section 4b for explanation of ranges of analogy; sometimes a mean of the 2 reference stations is used.

TABLE II: STATIONS USED IN TABLES OF MONTHLY VALUES

Stations	Elev (ft)	Lat	Long (W)	Period of Record (Yr) Temp.	Prec.
Ambato Ecuador	8,596	1° 10'S	78° 42'	5	5
Andagoya Colombia	250	5° 04'N	76° 55'	8	15
BALBOA HEIGHTS Canal Zone	118	8° 58'N	79° 35'	12	22
Belem Brazil	79	1° 28'S	48° 27'	12	15
Belo Horizonte Brazil	1,812	19° 56'S	43° 57'	18	18
Caracas Venezuela	3,420	10° 30'N	66° 53'	22	46
Cayenne French Guiana	20	4° 58'N	52° 18'	23	51
CRISTOBAL Canal Zone	36	9° 25'N	79° 52'	7	8
Cuyaba Brazil	541	15° 35'S	56° 06'	15	29
Dadanawa British Guiana	625	2° 30'N	59° 30'	9	9
Guayaquil Ecuador	40	2° 15'S	79° 52'	3	3
Huancayo Peru	11,000	12° 02'S	75° 20'	12	12
Imperatriz Brazil	429	5° 32'S	47° 27'	7	7
Lima Peru	518	12° 02'S	77° 02'	10	18
Manaos Brazil	147	3° 08'S	60° 01'	10	27
Maracaibo Venezuela	26	10° 38'N	71° 37'	15	22
Merida Venezuela	5,384	8° 36'N	71° 05'	9	19
Morro do Chapeu Brazil	997	11° 31'S	41° 14'	6	13
Natal Brazil	52	5° 46'S	35° 12'	18	13
Porto Velho Brazil	407	8° 46'S	63° 55'	14	14
Pucallpa Peru	495	8° 23'S	74° 32'	7	7
Rio de Janeiro Brazil	149	22° 54'S	43° 10'	38	84
Salvador Brazil	689	13° 00'S	38° 31'	11	7
Sucre Bolivia	9,344	19° 03'S	65° 17'	5	52
Tingo Maria Peru	2,204	9° 18'S	76° 00'	16	16

TABLE III: MEAN MONTHLY TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Ambato	58	58	58	58	57	56	54	54	56	58	58	58	57
Andagoya	82	82	82	82	82	82	81	81	81	82	81	81	82
BALBOA HEIGHTS	78	79	80	80	79	79	79	79	79	78	78	78	79
Belem	79	79	79	80	80	80	80	80	80	80	80	80	80
Belo Horizonte	72	73	72	69	66	62	63	65	68	70	70	71	68
Caracas	64	65	66	68	69	69	68	68	68	68	67	65	67
Cayenne	79	80	80	80	80	80	80	82	83	83	83	80	81
CRISTOBAL	80	80	81	82	81	81	81	81	81	80	80	80	81
Cuyaba	80	79	79	78	75	72	72	75	78	81	81	80	78
Dadanawa	82	82	83	83	82	81	81	82	84	85	85	82	83
Guayaquil	79	79	79	80	79	77	75	76	77	77	78	80	78
Huancayo	55	55	54	54	52	50	49	51	54	55	56	55	53
Imperatriz	76	76	76	76	76	73	72	74	76	77	77	77	76
Lima	73	74	74	70	66	63	61	61	61	63	66	69	67
Manaos	79	80	79	79	80	80	80	81	82	82	81	80	80
Maracaibo	81	82	83	84	84	85	85	85	84	82	82	82	83
Merida	65	66	66	68	68	68	68	68	68	67	66	65	67
Morro do Chapeu	69	69	69	68	65	63	62	62	65	68	68	68	66
Natal	82	81	81	79	79	77	75	76	78	80	81	81	79
Porto Velho	81	81	81	81	81	80	80	82	83	82	82	81	81
Pucallpa	80	80	80	79	79	78	76	79	80	80	80	80	79
Rio de Janeiro	78	79	77	75	72	69	68	69	70	72	74	76	73
Salvador	80	80	80	79	77	75	74	74	76	77	78	79	77
Sucre	55	55	56	55	52	50	50	53	56	56	58	57	54
Tingo Maria	76	75	76	76	76	75	74	76	77	77	76	76	76

TABLE IV: MEAN DAILY MAXIMUM TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Ambato	70	69	70	70	68	67	65	66	67	70	72	70	69
Andagoya	90	89	90	90	89	89	89	89	89	90	88	88	89
BALBOA HEIGHTS	88	89	90	90	87	86	87	87	86	85	85	87	87
Belem	86	86	86	87	88	88	88	88	89	89	89	88	88
Belo Horizonte	81	81	82	81	76	76	76	78	81	80	80	79	79
Caracas	75	77	78	80	80	78	77	78	79	79	77	75	78
Cayenne	84	84	85	85	85	86	88	90	91	91	88	86	87
CRISTOBAL	84	84	85	86	86	86	85	85	86	86	84	84	85
Cuyaba	91	91	91	91	88	88	90	93	92	92	91	90	91
Dadanawa	93	92	93	92	90	89	90	92	94	97	96	93	93
Guayaquil	82	82	82	83	83	81	80	81	81	81	81	85	82
Huancayo	65	65	65	67	67	66	66	67	67	68	69	67	67
Imperatriz	87	87	87	88	89	90	92	92	93	93	91	88	90
Lima	80	82	81	77	72	67	65	65	66	68	72	76	72
Manaos	88	88	88	87	88	88	89	91	92	92	91	90	89
Maracaibo	88	89	90	91	91	92	92	92	91	88	87	88	90
Merida	73	74	74	75	76	76	77	77	77	75	74	73	75
Morro do Chapeu	77	79	81	78	74	72	71	72	76	80	80	81	77
Natal	86	85	86	86	85	83	82	82	84	85	85	86	85
Porto Velho	85	85	85	86	86	86	88	90	91	88	87	85	87
Pucallpa	89	88	88	87	88	88	87	91	91	90	88	89	89
Rio de Janeiro	84	85	83	80	77	75	75	76	75	77	79	82	79
Salvador	87	87	87	86	83	80	80	80	82	83	85	85	84
Sucre	63	61	64	63	63	61	61	65	67	65	68	66	64
Tingo Maria	86	85	85	87	87	86	86	88	88	87	88	86	86

TABLE V: MEAN DAILY MINIMUM TEMPERATURE (°F)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Ambato	49	48	48	49	49	47	46	45	46	47	47	48	47
Andagoya	74	74	74	75	74	74	74	74	73	74	74	74	74
BALBOA HEIGHTS	72	71	72	74	74	74	74	74	74	73	73	73	73
Belem	72	72	73	73	73	72	71	71	71	71	71	72	72
Belo Horizonte	65	65	64	62	56	52	52	54	59	62	63	64	60
Caracas	56	56	57	60	62	62	61	61	61	61	60	58	60
Cayenne	74	75	75	75	74	73	73	74	74	75	75	74	74
CRISTOBAL	76	77	77	78	77	76	77	76	76	75	76	77	76
Cuyaba	73	73	72	70	66	63	61	63	67	71	72	72	69
Dadanawa	72	71	72	73	73	72	72	72	73	73	73	72	72
Guayaquil	75	77	77	77	75	74	70	72	74	72	73	76	74
Huancayo	44	44	43	41	36	35	32	35	41	42	42	43	40
Imperatriz	70	70	71	70	69	64	62	63	66	68	69	70	68
Lima	67	67	66	63	60	58	57	57	56	58	59	63	61
Manaos	75	75	75	75	75	75	74	75	75	76	76	75	75
Maracaibo	74	75	76	77	78	78	78	78	78	77	77	76	77
Merida	57	58	58	60	61	60	59	59	59	60	59	57	59
Morro do Chapeu	59	60	60	59	56	54	53	53	54	57	58	59	57
Natal	76	76	75	73	72	71	69	69	72	75	76	77	73
Porto Velho	76	76	76	76	75	73	72	74	76	76	76	76	75
Pucallpa	72	72	72	71	69	68	66	67	69	71	71	72	70
Rio de Janeiro	73	73	72	69	66	64	63	63	65	66	68	71	68
Salvador	73	74	73	73	72	70	69	69	70	71	72	73	72
Sucre	48	48	47	45	40	38	37	40	44	46	48	49	44
Tingo Maria	66	67	67	67	66	64	63	64	65	65	66	66	65

TABLE VI: MEAN MONTHLY PRECIPITATION (inches)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Ambato	1.8	1.7	2.2	2.6	2.1	0.7	0.9	0.7	1.0	1.5	1.4	1.3	17.9
Andagoya	24.9	21.4	19.5	26.1	25.5	25.7	23.3	25.3	24.6	22.7	22.4	19.5	280.9
BALBOA HEIGHTS	1.0	0.6	0.7	2.9	8.0	8.4	7.3	7.8	8.2	10.2	10.5	4.7	70.3
Belem	9.2	13.6	17.3	16.7	11.7	9.1	3.1	3.0	1.8	3.3	1.1	4.2	94.1
Belo Horizonte	11.5	7.5	4.9	4.0	0.9	0.4	0.5	0.8	1.6	5.1	9.1	12.4	58.8
Caracas	0.9	0.4	0.5	1.3	3.1	4.0	4.3	4.3	4.2	4.3	3.7	1.8	32.8
Cayenne	14.4	12.3	15.8	18.9	21.9	15.5	6.9	2.8	1.2	1.3	4.6	10.7	126.3
CRISTOBAL	3.4	1.5	1.5	4.1	12.5	13.9	15.6	15.3	12.8	15.8	22.3	11.7	130.4
Cuyaba	10.0	8.6	8.0	4.0	2.2	0.5	0.3	1.1	1.8	5.2	6.0	8.1	55.8
Dadanawa	1.3	2.2	2.2	5.6	7.7	13.8	10.2	8.0	2.6	1.6	1.1	2.0	58.3
Guayaquil	9.7	10.5	7.4	5.3	2.1	0.7	0.4	0.0	0.2	0.4	0.3	1.9	39.0
Huancayo	5.4	4.1	4.8	2.0	0.9	0.4	0.2	0.5	2.1	2.7	2.5	3.3	29.1
Imperatriz	10.1	10.4	9.6	6.0	3.7	0.5	0.5	0.8	0.9	2.5	3.3	6.5	54.8
Lima	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.4	0.2	0.1	0.0	1.9
Manaos	9.8	9.2	9.8	8.6	7.0	3.8	2.3	1.4	2.0	4.1	6.0	7.8	71.8
Maracaibo	0.1	0.0	0.3	0.5	2.5	2.5	2.1	2.4	3.0	4.8	3.3	0.6	22.3
Merida	2.4	1.5	3.3	7.0	10.1	7.4	4.9	5.8	7.9	10.3	8.5	3.4	71.5
Morro do Chapeu	3.9	4.3	4.0	3.5	1.8	2.0	1.9	1.5	1.0	2.5	3.9	4.0	33.9
Natal	3.1	4.9	5.7	9.0	7.1	10.5	7.7	3.6	3.4	1.0	0.6	1.2	57.7
Porto Velho	14.5	13.5	15.0	8.9	5.0	1.4	0.6	2.1	4.1	8.9	11.2	13.8	98.6
Pucallpa	4.2	5.1	7.3	7.4	4.1	2.3	2.1	1.8	2.6	5.5	7.5	7.2	58.2
Rio de Janeiro	4.9	4.8	5.1	4.2	3.1	2.1	1.6	1.7	2.6	3.1	4.1	5.4	42.6
Salvador	3.8	2.9	6.5	12.0	10.9	8.1	6.9	3.2	3.3	2.0	3.7	1.9	65.3
Sucre	7.3	4.9	3.7	1.6	0.2	0.1	0.2	0.3	1.0	1.6	2.6	4.3	27.8
Tingo Maria	17.3	16.3	16.6	9.8	7.9	7.4	5.9	4.0	6.0	11.5	11.7	16.4	130.5

TABLE VII: MEAN CLOUDINESS (tenths of sky covered)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr.
Ambato	7.6	7.5	7.9	7.9	7.9	7.5	8.1	7.9	7.7	7.4	7.1	7.4	7.7
Andagoya*	---	---	---	---	---	---	---	---	---	---	---	---	---
BALBOA HEIGHTS	4.8	4.8	5.0	6.3	7.6	8.0	7.6	7.7	7.7	7.7	7.6	6.3	6.8
Belem	6.5	7.4	7.4	7.1	6.1	5.1	4.4	4.0	3.8	3.9	4.2	5.3	5.4
Belo Horizonte	6.2	5.3	5.5	4.8	4.0	3.8	3.5	3.3	4.3	5.4	6.3	6.8	4.9
Caracas	5.2	4.9	5.8	7.2	7.9	8.4	7.9	7.5	7.1	6.9	7.1	6.1	6.8
Cayenne	7.2	6.8	7.1	6.6	7.2	6.5	5.5	4.6	4.1	4.0	5.0	5.7	5.8
CRISTOBAL	5.9	5.5	5.8	6.4	7.8	7.9	8.0	7.6	7.1	7.4	7.6	6.8	7.0
Cuyaba	7.3	7.1	7.1	5.6	4.4	4.3	3.6	3.5	4.8	6.0	6.6	7.6	5.7
Dadanawa*	---	---	---	---	---	---	---	---	---	---	---	---	---
Guayaquil	7.0	8.1	8.1	7.0	7.0	7.3	5.7	7.0	7.0	7.6	7.0	8.0	7.2
Huancayo*	---	---	---	---	---	---	---	---	---	---	---	---	---
Imperatriz	6.8	6.9	6.2	5.7	3.8	2.5	3.2	2.0	3.1	4.0	4.2	6.0	4.5
Lima	5.9	5.6	4.8	4.7	6.2	8.2	8.9	9.1	8.6	7.9	6.5	6.0	6.9
Manaos	6.6	6.9	6.8	6.9	6.6	6.3	5.5	6.0	6.1	6.3	6.4	6.7	6.4
Maracaibo	2.6	2.9	2.6	4.3	4.0	4.0	3.6	4.6	4.3	4.5	3.9	2.9	3.7
Merida*	---	---	---	---	---	---	---	---	---	---	---	---	---
Morro do Chapeu	5.6	6.2	5.8	5.8	6.0	5.8	5.9	6.0	5.4	5.7	5.9	6.2	5.9
Natal	5.1	5.4	5.1	5.8	5.8	6.1	5.1	4.7	4.2	4.1	4.4	5.0	5.1
Porto Velho*	---	---	---	---	---	---	---	---	---	---	---	---	---
Pucallpa*	---	---	---	---	---	---	---	---	---	---	---	---	---
Rio de Janeiro	6.6	5.9	6.0	5.9	5.6	5.3	5.0	5.6	7.0	6.9	6.9	6.8	6.1
Salvador	5.5	5.0	5.4	6.0	6.3	6.4	6.4	5.1	5.6	5.8	5.5	5.8	5.7
Sucre	8.5	8.6	7.2	5.5	4.4	4.1	4.0	3.3	5.2	7.2	7.7	8.0	6.1
Tingo Maria*	---	---	---	---	---	---	---	---	---	---	---	---	---

* No data available

TABLE VIII: MEAN RELATIVE HUMIDITY (%)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Ambato	74	76	75	76	76	76	75	75	73	74	72	73	75
Andagoya*	--	--	--	--	--	--	--	--	--	--	--	--	--
BALBOA HEIGHTS	78	75	73	77	85	87	86	87	87	88	88	84	83
Belem	93	93	92	91	89	86	87	87	86	86	85	89	89
Belo Horizonte	77	76	76	76	72	69	70	69	68	71	71	75	72
Caracas	78	76	76	76	77	80	80	80	80	81	82	81	79
Cayenne	82	80	81	80	84	82	80	76	73	74	78	81	79
CRISTOBAL	78	77	77	79	83	85	86	86	85	85	86	82	82
Cuyaba	78	80	80	79	75	72	64	60	59	68	74	77	72
Dadanawa	89	82	84	88	82	96	91	92	76	86	85	88	87
Guayaquil*	--	--	--	--	--	--	--	--	--	--	--	--	--
Huancayo*	--	--	--	--	--	--	--	--	--	--	--	--	--
Imperatriz	95	95	92	95	95	93	90	86	84	85	88	92	91
Lima	79	77	78	80	79	88	86	85	85	82	82	80	82
Manaos	80	81	81	82	82	80	77	75	74	74	76	80	79
Maracaibo	78	78	72	76	79	80	77	78	82	86	84	79	79
Merida	76	75	77	79	81	80	78	78	78	81	81	80	79
Morro do Chapeu	80	78	78	82	85	85	85	80	75	73	77	76	80
Natal	76	76	76	80	80	81	81	78	76	76	75	75	78
Porto Velho*	--	--	--	--	--	--	--	--	--	--	--	--	--
Pucallpa*	--	--	--	--	--	--	--	--	--	--	--	--	--
Rio de Janeiro	78	78	80	79	79	79	78	76	79	79	79	78	78
Salvador	83	83	83	84	84	84	83	83	83	83	83	84	83
Sucre	70	69	69	68	53	48	50	52	56	60	59	64	60
Tingo Maria*	--	--	--	--	--	--	--	--	--	--	--	--	--

*No data available

TABLE IX: MEAN WIND SPEED (mph)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr.
Ambato	2.7	2.2	2.5	2.2	2.2	2.2	2.9	2.9	2.7	2.7	2.7	2.9	2.6
Andagoya*	---	---	---	---	---	---	---	---	---	---	---	---	---
BALBOA HEIGHTS	8.8	10.1	10.3	8.8	6.1	5.4	5.9	5.9	5.6	6.3	5.8	6.4	7.1
Belem*	---	---	---	---	---	---	---	---	---	---	---	---	---
Belo Horizonte	2.5	2.5	3.1	2.5	2.7	2.5	2.5	3.8	3.6	3.1	2.5	2.2	2.7
Caracas	6.9	8.0	8.8	7.9	7.8	8.5	7.8	6.5	6.2	6.2	6.3	6.7	7.3
Cayenne	9.6	13.7	10.1	8.1	6.0	5.1	5.1	6.4	7.7	6.0	6.0	6.4	7.2
CRISTOBAL	14.1	14.8	14.8	12.5	8.0	6.6	8.1	7.9	6.1	6.6	8.0	11.8	9.9
Cuyaba	4.7	3.6	3.3	2.9	2.9	2.9	2.9	3.3	2.9	3.6	3.3	3.6	3.3
Dadanawa*	---	---	---	---	---	---	---	---	---	---	---	---	---
Guayaquil	2.9	2.9	3.4	3.1	2.9	2.9	3.4	3.4	4.0	4.7	4.0	3.1	4.1
Huancayo*	---	---	---	---	---	---	---	---	---	---	---	---	---
Imperatriz	0.7	1.3	0.7	0.9	0.4	0.7	0.7	1.1	0.9	0.7	0.7	0.4	0.7
Lima	4.5	4.5	3.6	3.1	2.9	3.4	3.6	4.3	5.7	5.4	5.1	5.4	4.3
Manaos	3.8	4.3	3.8	3.8	3.4	4.0	3.8	4.3	4.5	4.3	4.3	3.8	4.0
Maracaibo	4.6	5.2	5.0	5.4	4.5	3.7	5.1	4.8	4.3	4.3	4.8	4.3	4.7
Merida*	---	---	---	---	---	---	---	---	---	---	---	---	---
Morro do Chapeu	4.7	4.4	4.0	4.4	5.5	6.8	6.8	6.8	6.0	3.3	3.6	4.7	5.1
Natal	13.2	10.6	10.1	10.1	10.6	12.1	11.6	14.2	15.9	15.9	14.8	14.8	12.6
Porto Velho*	---	---	---	---	---	---	---	---	---	---	---	---	---
Pucallpa*	---	---	---	---	---	---	---	---	---	---	---	---	---
Rio de Janeiro	7.2	7.4	7.4	6.5	6.0	5.6	5.8	6.5	7.6	8.5	8.9	8.9	7.2
Salvador	4.7	4.7	4.7	6.0	6.8	6.4	7.2	6.8	5.5	6.8	6.4	6.0	6.0
Sucre	5.1	5.4	5.8	5.3	5.2	4.7	4.9	5.5	6.7	6.9	6.5	6.0	5.7
Tingo Maria*	---	---	---	---	---	---	---	---	---	---	---	---	---

*No data available

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9. Acknowledgements

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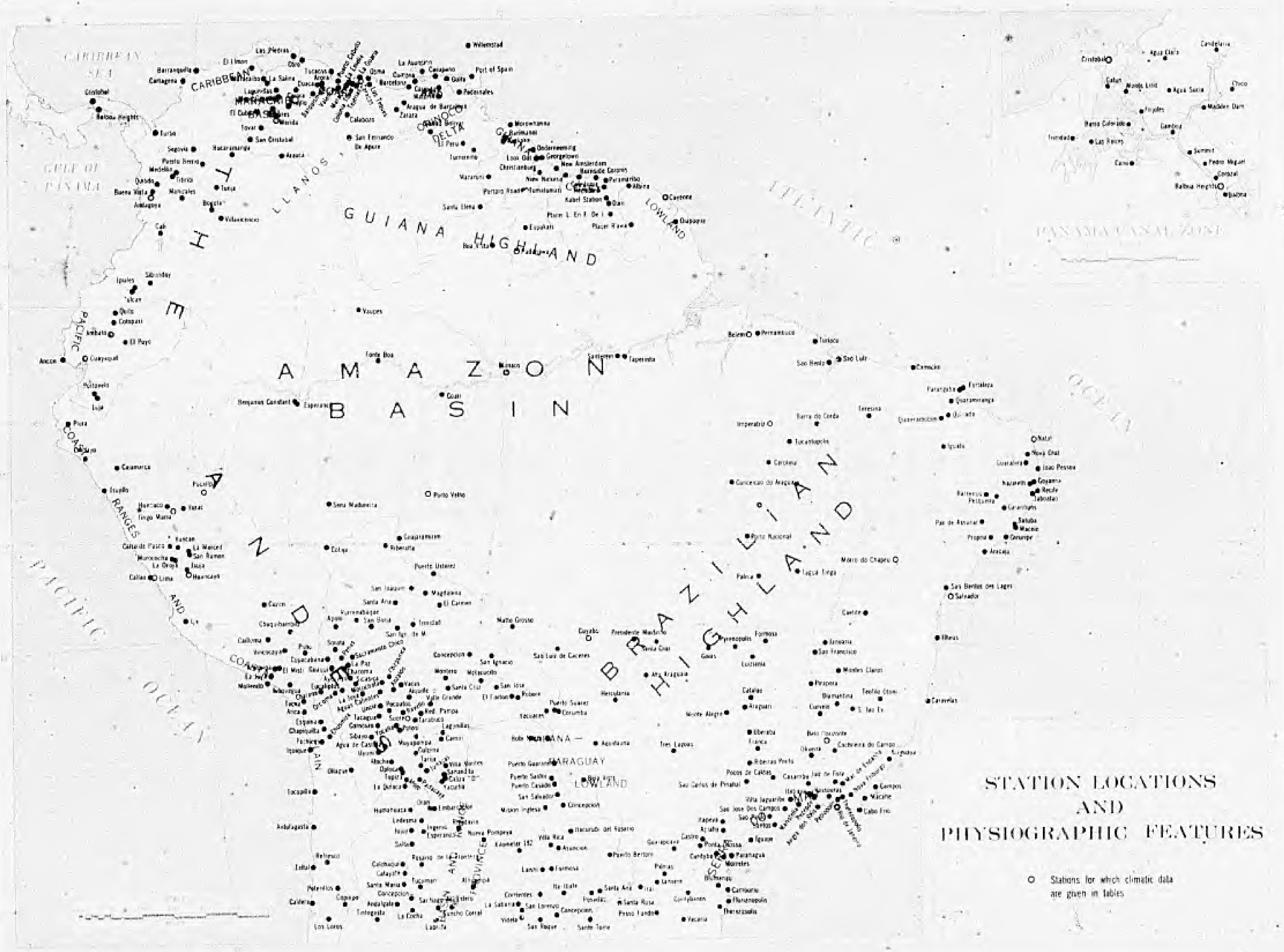
10. Maps

Figure	
2	Station Locations
3	Mean Temperature, Warmest Month
4	Mean Daily Maximum Temperature, Warmest Month
5	Mean Temperature, Coldest Month
6	Mean Daily Minimum Temperature, Coldest Month
7	Mean Daily Temperature Range, Warmest Month
8	Mean Annual Precipitation

CLIMATIC ANALOGS OF PANAMA CANAL ZONE — SOUTH AMERICA



STATION LOCATIONS
AND
PHYSIOGRAPHIC FEATURES

○ Stations for which climatic data are given in tables

Figure 2

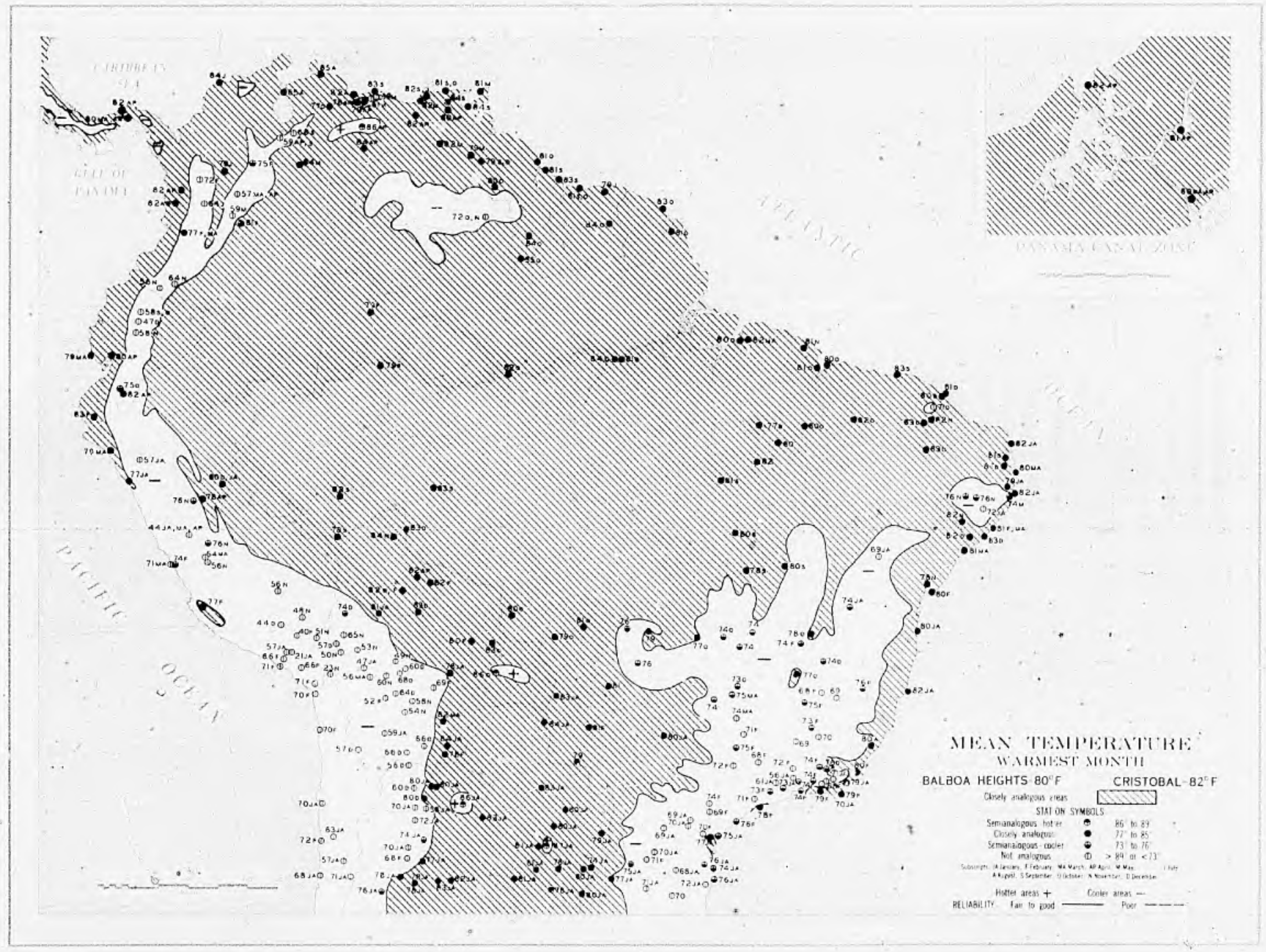

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
ATLANTIC OCEAN
PANAMA CANAL ZONE
MEAN TEMPERATURE
WARMEST MONTH
BALBOA HEIGHTS 80°F
CRISTOBAL 82°F
Closely analogous areas
STATION SYMBOLS
Semianalogous hotter
Closely analogous
Semianalogous cooler
Not analogous
86° to 89°
77° to 85°
73° to 76°
> 89° or < 73°
Hotter areas +
Cooler areas —
RELIABILITY Fair to good
Poor

Figure 3

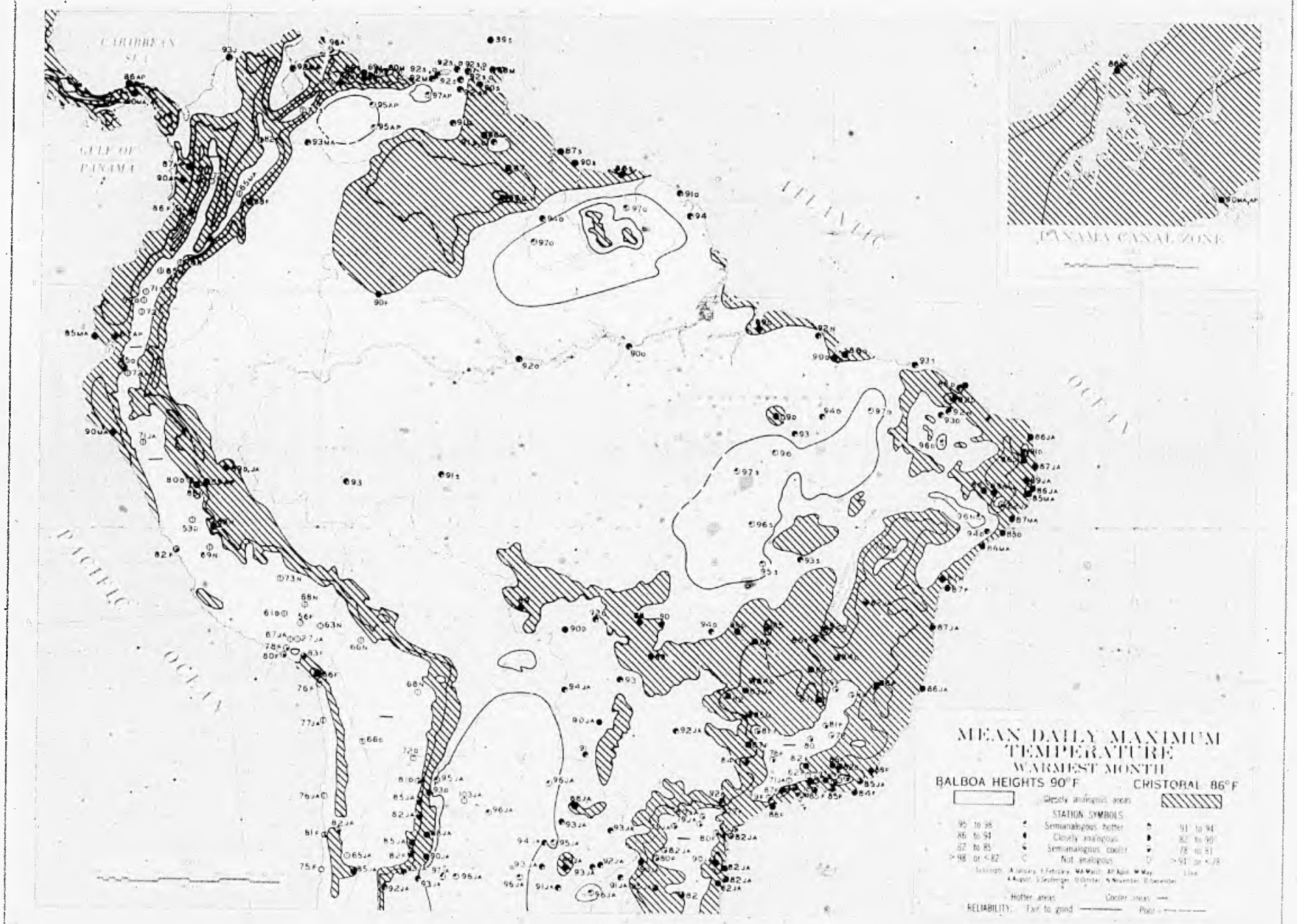

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
ATLANTIC OCEAN
PANAMA CANAL ZONE
MEAN DAILY MAXIMUM TEMPERATURE
WARMEST MONTH
BALBOA HEIGHTS 90°F
CRISTOBAL 86°F
Closely analogous areas
STATION SYMBOLS
95 to 98 — Semianalogous hotter — 91 to 94
86 to 94 — Closely analogous — 82 to 90
82 to 85 — Semianalogous cooler — 78 to 81
>98 or <82 — Not analogous — >94 or <78
Hotter areas
Cooler areas
RELIABILITY: Fair to good
Poor

Figure 4

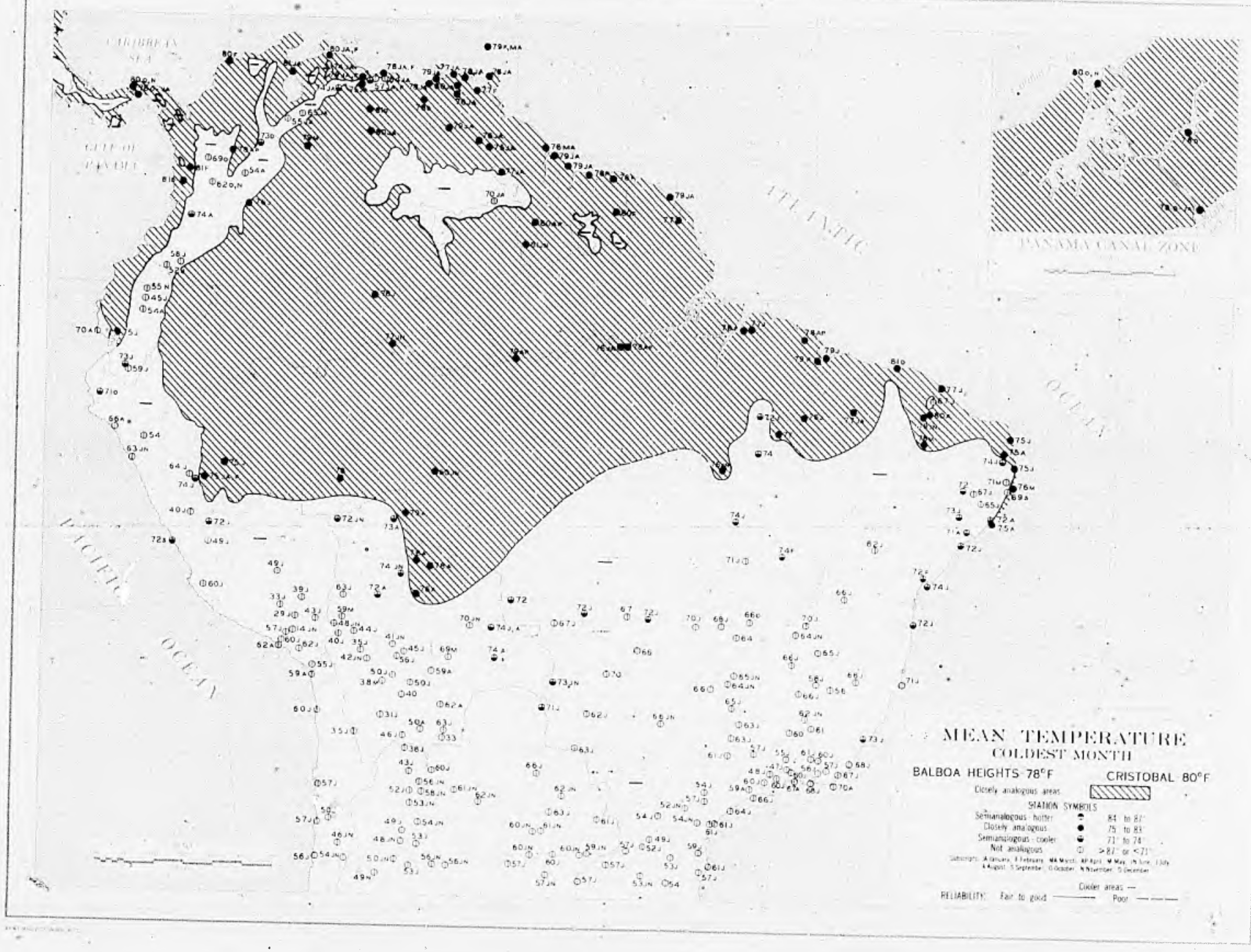

CARIBBEAN SEA
GULF OF PANAMA
ATLANTIC OCEAN
PACIFIC OCEAN
PANAMA CANAL ZONE
MEAN TEMPERATURE
COLDEST MONTH
BALBOA HEIGHTS 78°F
CRISTOBAL 80°F
Closely analogous areas
STATION SYMBOLS
Semianalogous - hotter 84° to 87°
Closely analogous 75° to 83°
Semianalogous - cooler 71° to 74°
Not analogous >87° or <71°
Cooler areas
RELIABILITY: Fair to good
Poor

Figure 5

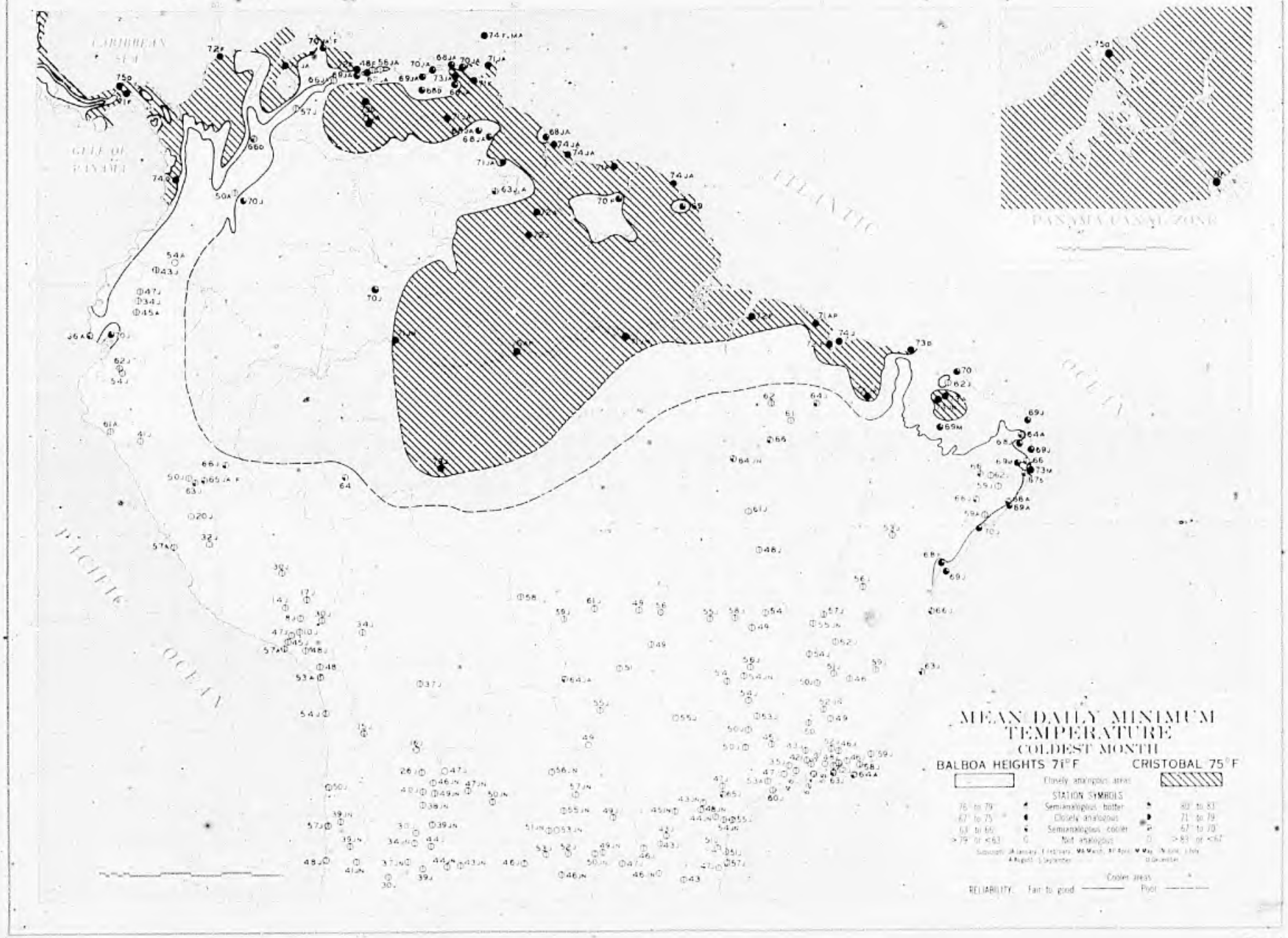

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
ATLANTIC OCEAN
PANAMA CANAL ZONE
MEAN DAILY MINIMUM TEMPERATURE
COLDEST MONTH
BALBOA HEIGHTS 71°F
CRISTOBAL 75°F
Closely analogous areas
STATION SYMBOLS
76° to 79°
71° to 75°
67° to 70°
Semianalogous hotter
Closely analogous
Semianalogous cooler
Not analogous
80° to 83°
71° to 79°
67° to 70°
>83° or <67°
Cooler areas
RELIABILITY. Fair to good
Poor

Figure 6

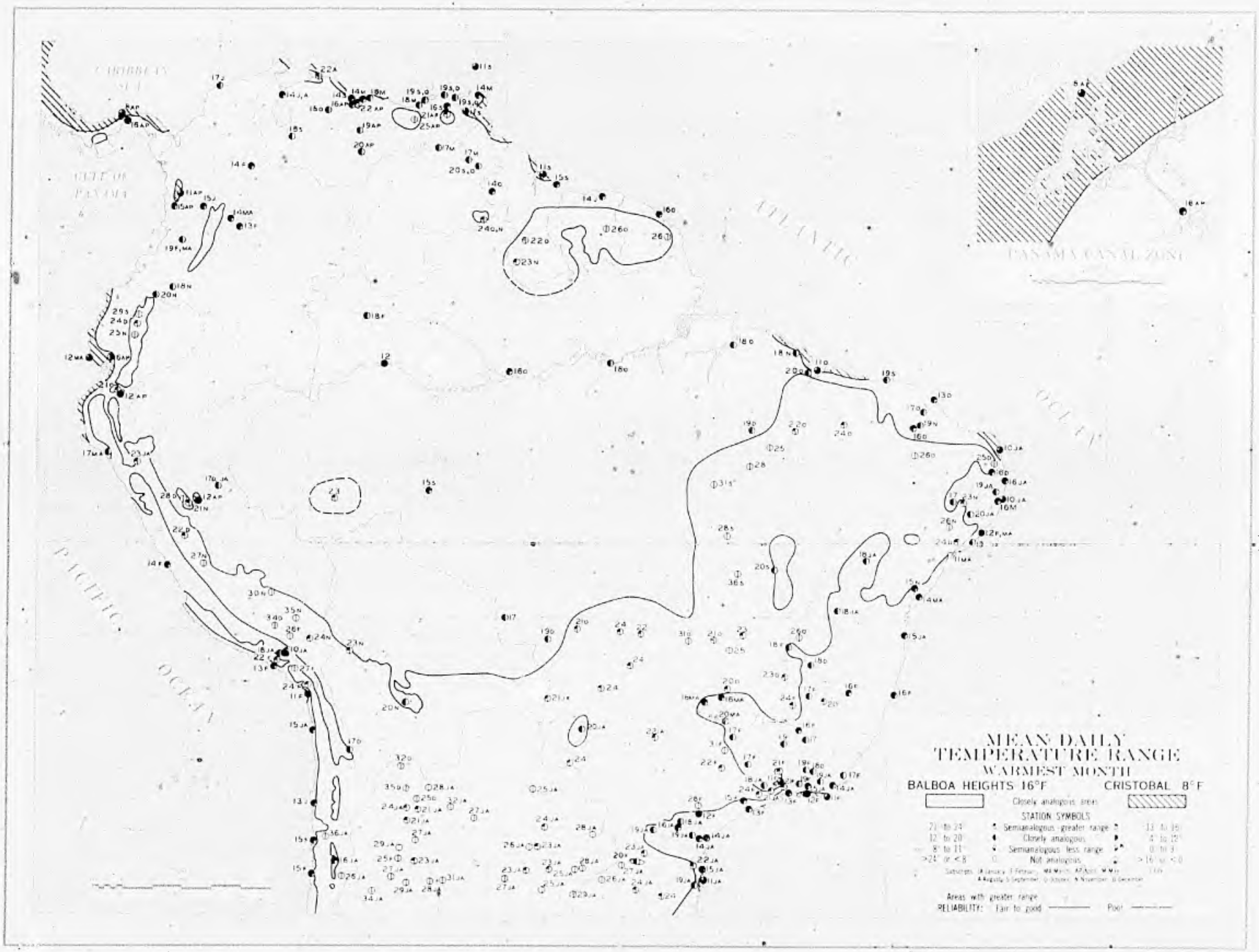

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
ATLANTIC OCEAN
PANAMA CANAL ZONE
MEAN DAILY TEMPERATURE RANGE
WARMEST MONTH
BALBOA HEIGHTS 16°F
CRISTOBAL 8°F
Closely analogous areas
STATION SYMBOLS
21° to 24°
12° to 20°
8° to 11°
>24° or <8°
Semianalogous greater range
Closely analogous
Semianalogous less range
Not analogous
13° to 16°
4° to 12°
0° to 3°
>16° or <0°
Areas with greater range
RELIABILITY: Fair to good
Poor

Figure 7

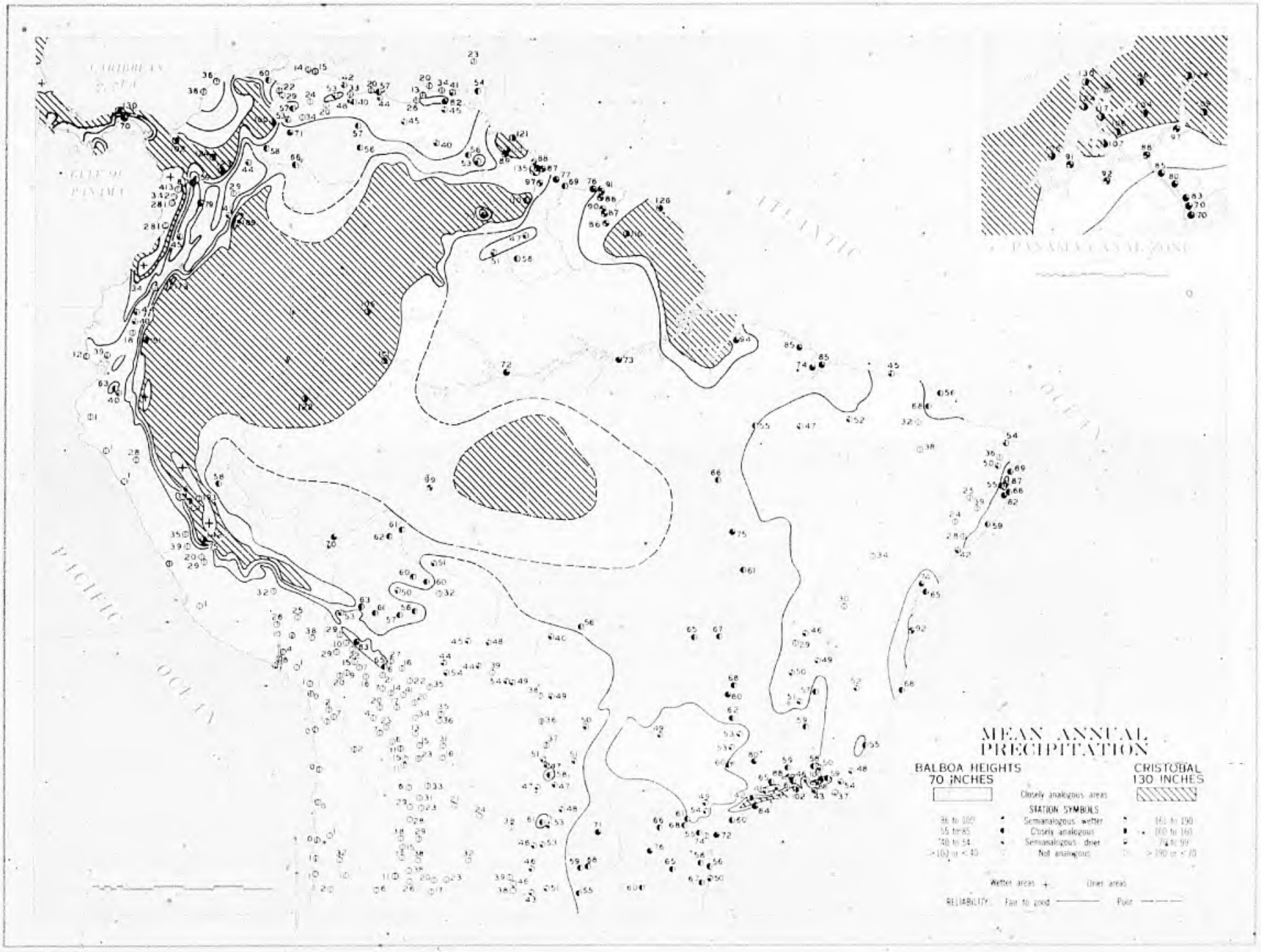

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
ATLANTIC OCEAN
PANAMA CANAL ZONE
MEAN ANNUAL PRECIPITATION
BALBOA HEIGHTS 70 INCHES
CRISTOBAL 130 INCHES
Closely analogous areas
STATION SYMBOLS
86 to 109 — Semianalogous - wetter — 161 to 190
55 to 85 — Closely analogous — 100 to 160
30 to 54 — Semianalogous - drier — 70 to 99
< 10 or < 30 — Not analogous — > 190 or < 70
Wetter areas + Drier areas
RELIABILITY: Fair to good —— Poor ——

Figure 8

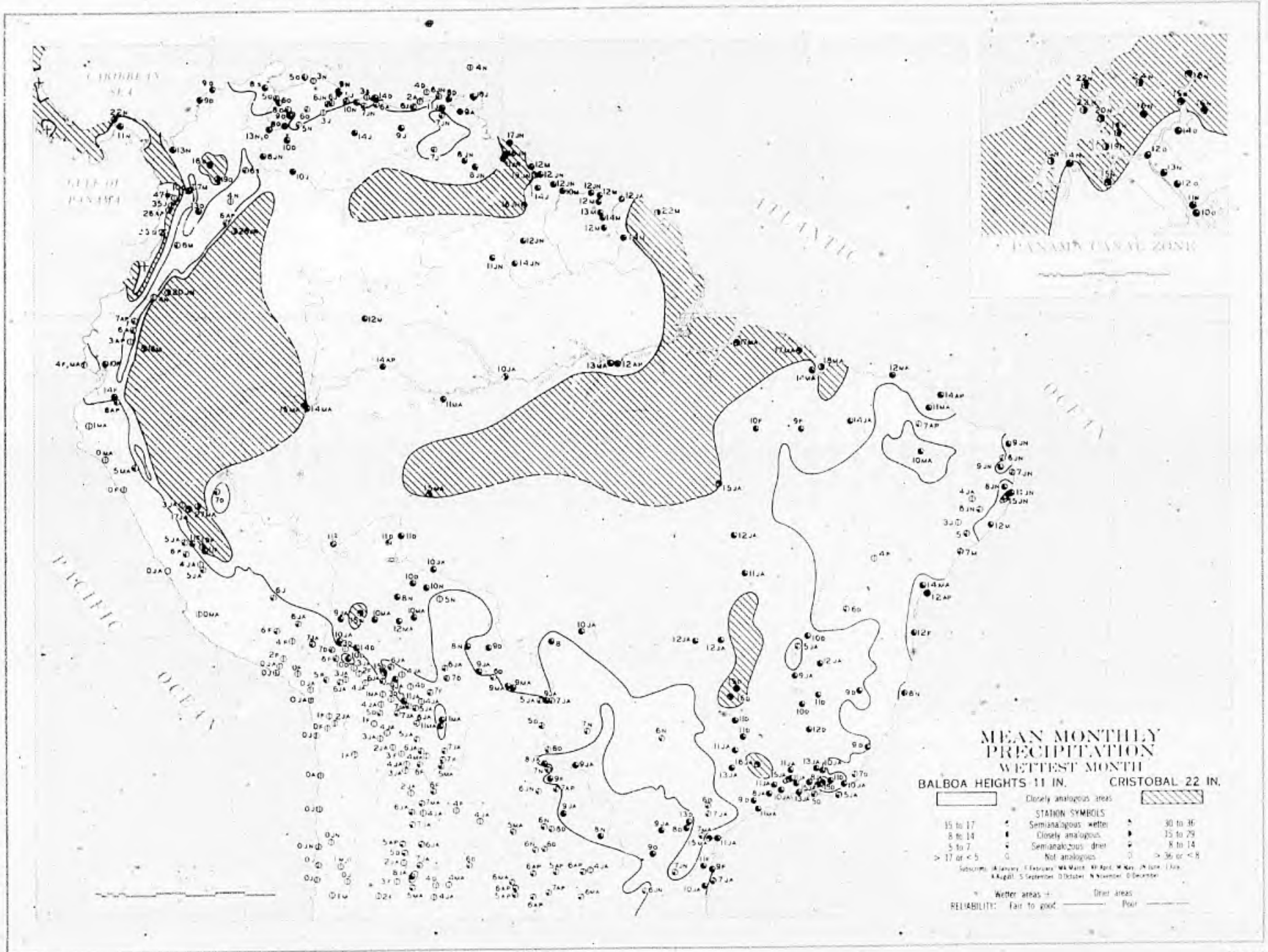

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
ATLANTIC OCEAN
PANAMA CANAL ZONE
MEAN MONTHLY PRECIPITATION
WETTEST MONTH
BALBOA HEIGHTS 11 IN.
CRISTOBAL 22 IN.
Closely analogous areas
STATION SYMBOLS
15 to 17 — Semianalogous wetter — 30 to 36
8 to 14 — Closely analogous — 15 to 29
5 to 7 — Semianalogous drier — 8 to 14
> 17 or < 5 — Not analogous — > 36 or < 8
Subscripts: (A)January (F)February (MA)March (AP)April (M)May (JN)June (JA)July (A)August (S)September (O)October (N)November (D)December
Wetter areas +
Drier areas
RELIABILITY: Fair to good
Poor

Figure 9

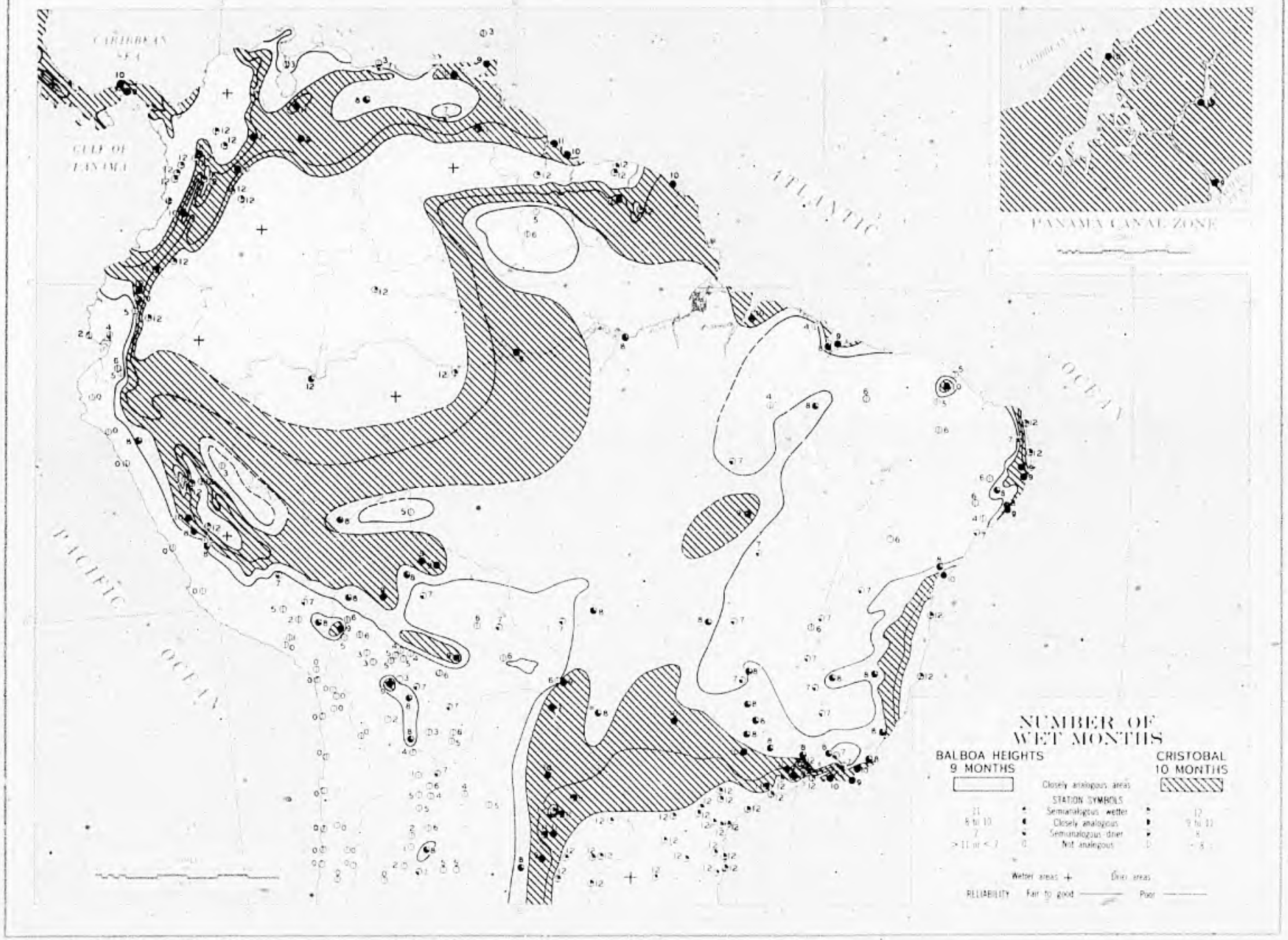

CARIBBEAN SEA
GULF OF PANAMA
ATLANTIC OCEAN
PACIFIC OCEAN
PANAMA CANAL ZONE
NUMBER OF WET MONTHS
BALBOA HEIGHTS
9 MONTHS
CRISTOBAL
10 MONTHS
Closely analogous areas
STATION SYMBOLS
11
8 to 10
7
> 11 or < 7
Semianalogous wetter
Closely analogous
Semianalogous drier
Not analogous
12
9 to 11
8
< 8
Wetter areas +
Drier areas
RELIABILITY
Fair to good
Poor

Figure 10

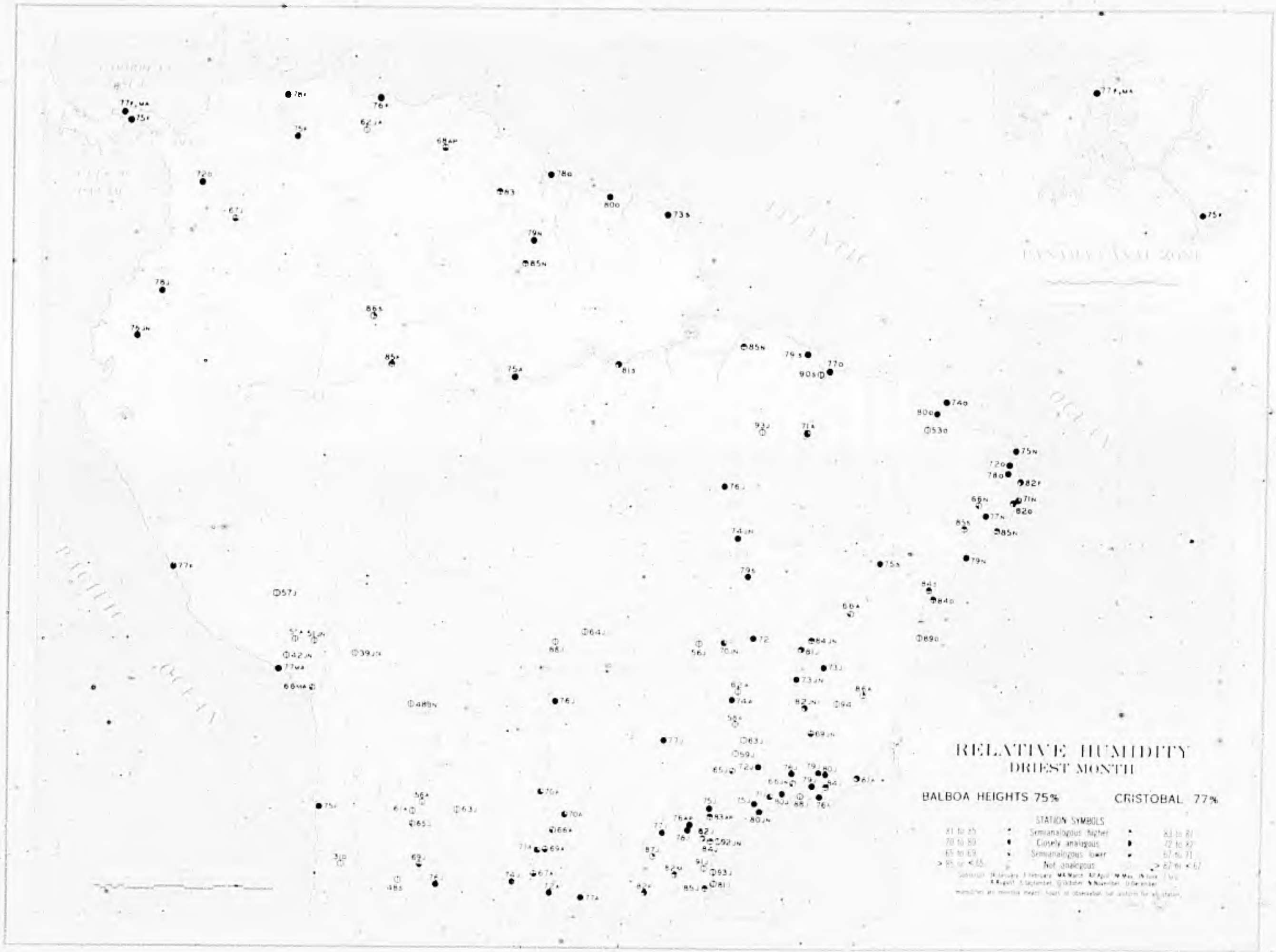

RELATIVE HUMIDITY
DRIEST MONTH
BALBOA HEIGHTS 75%
CRISTOBAL 77%
STATION SYMBOLS
81 to 85 Semianalogous higher
76 to 80 Closely analogous
65 to 69 Semianalogous lower
< 65 Not analogous
61 to 81
72 to 87
67 to 71
< 67

Figure 11

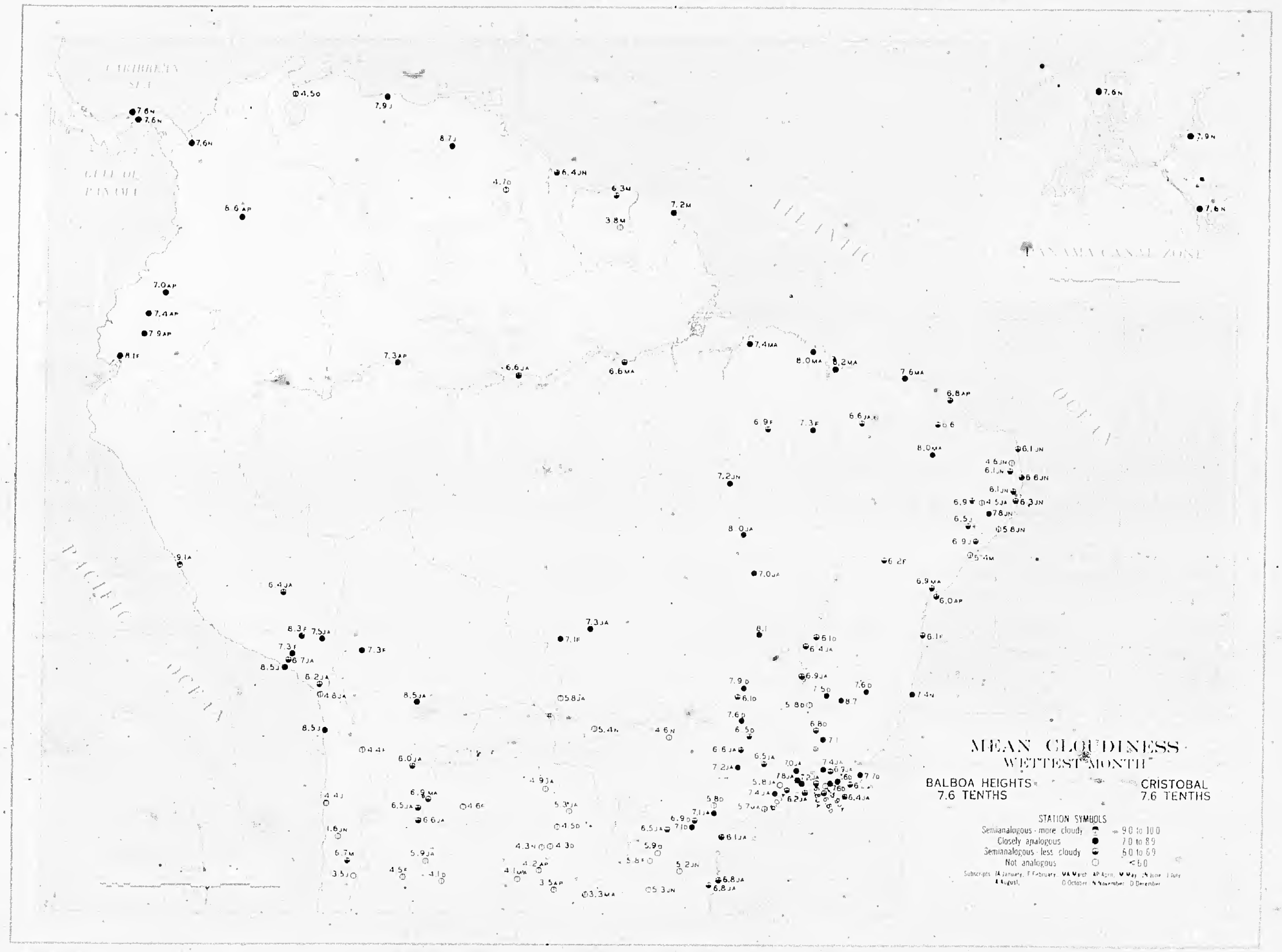

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
PANAMA CANAL ZONE
MEAN CLOUDINESS
WETTEST MONTH
BALBOA HEIGHTS
7.6 TENTHS
CRISTOBAL
7.6 TENTHS
STATION SYMBOLS
Semianalogous - more cloudy 9.0 to 10.0
Closely analogous 7.0 to 8.9
Semianalogous - less cloudy 6.0 to 6.9
Not analogous <6.0
Subscripts: JA January, F February, MA March, AP April, M May, JN June, JL July, A August, O October, N November, D December

Figure 12

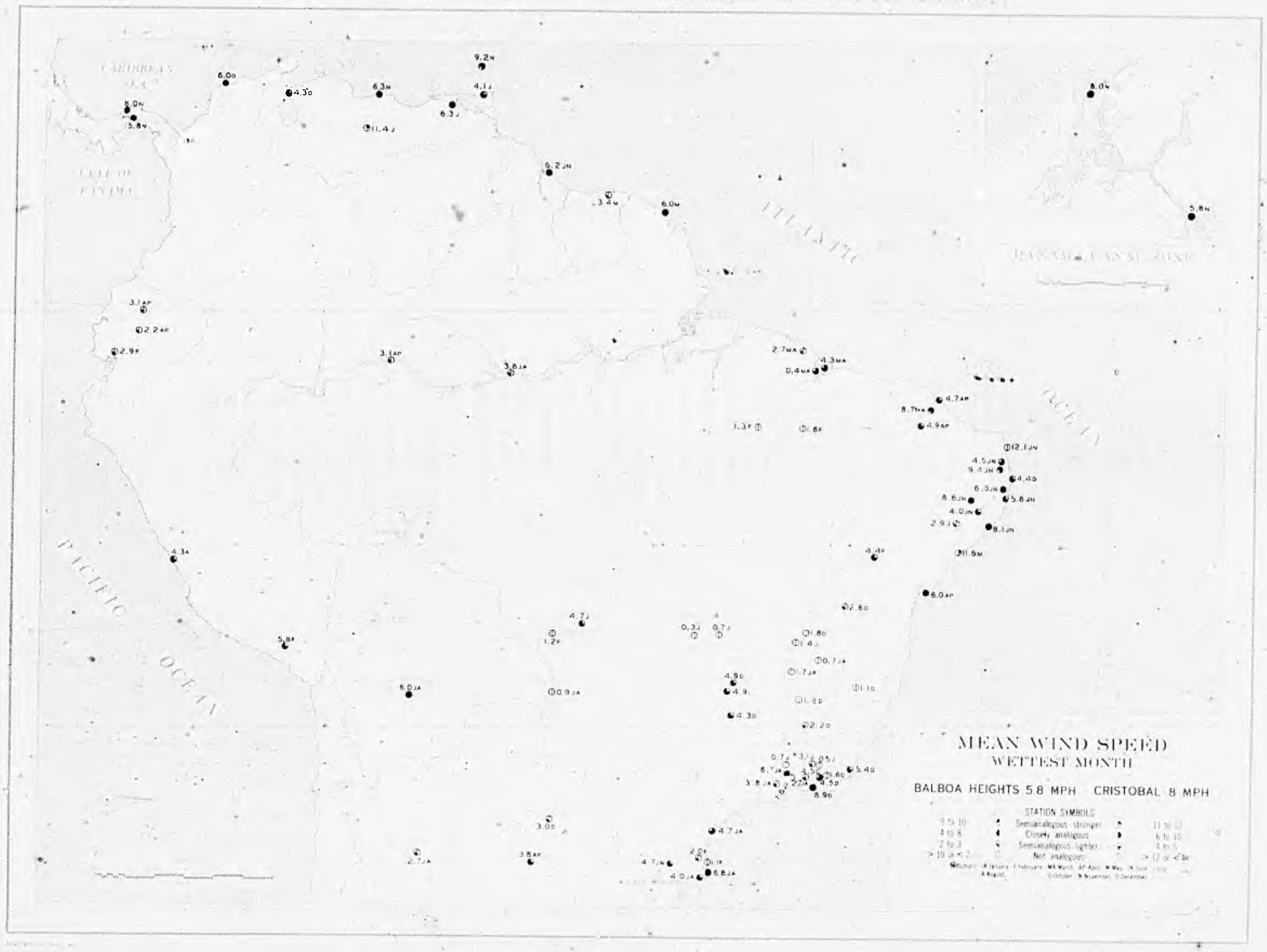

CARIBBEAN SEA
GULF OF PANAMA
PACIFIC OCEAN
ATLANTIC
PANAMA CANAL ZONE
MEAN WIND SPEED
WETTEST MONTH
BALBOA HEIGHTS 5.8 MPH CRISTOBAL 8 MPH
STATION SYMBOLS
9 to 10
4 to 8
2 to 3
> 10 or < 2
Semianalogous stronger
Closely analogous
Semianalogous lighter
Not analogous
11 to 12
6 to 10
4 to 5
> 12 or < 2

Figure 13

CLIMATIC ANALOGS OF PANAMA CANAL ZONE — SOUTH AMERICA

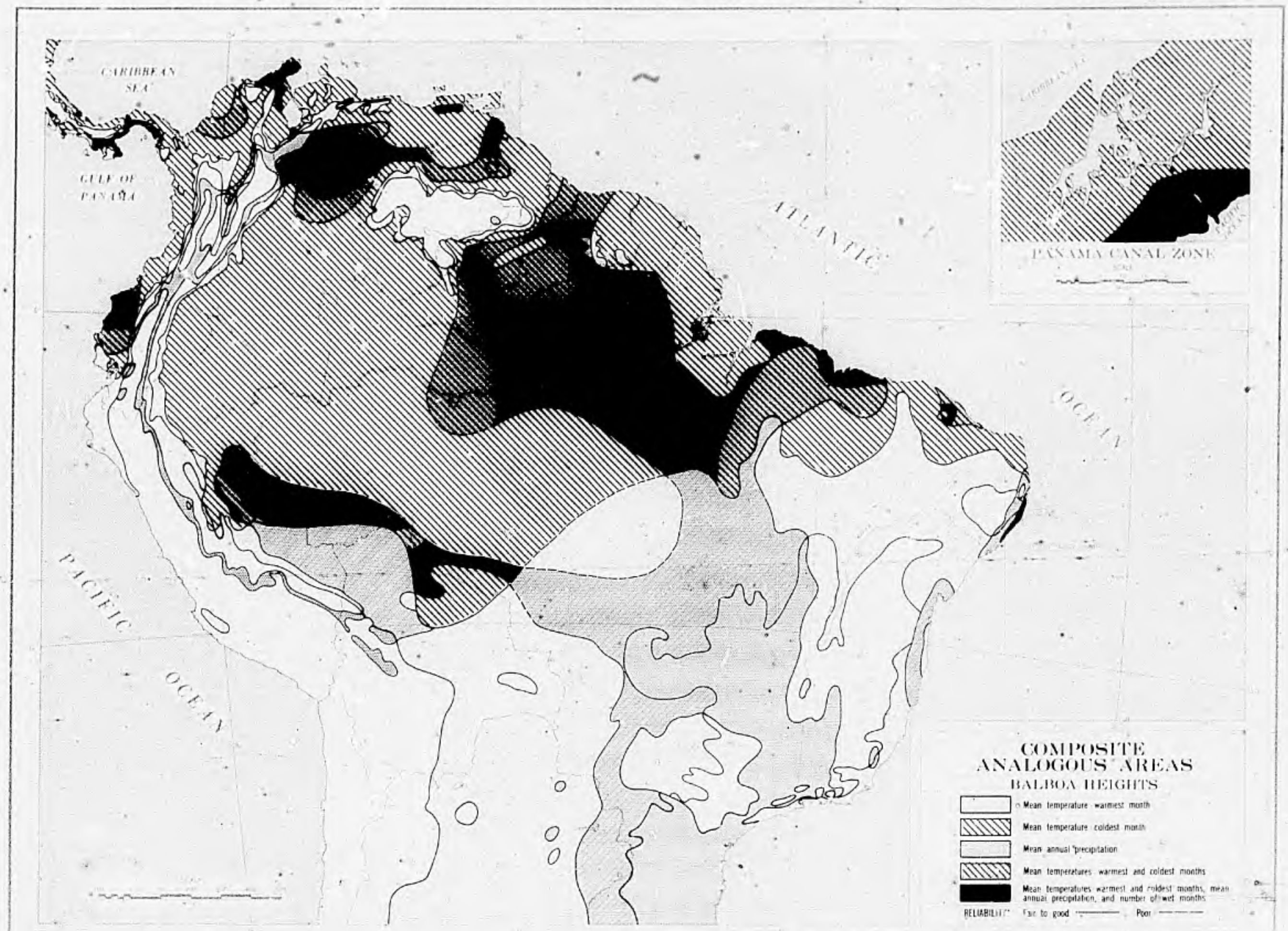


Figure 14

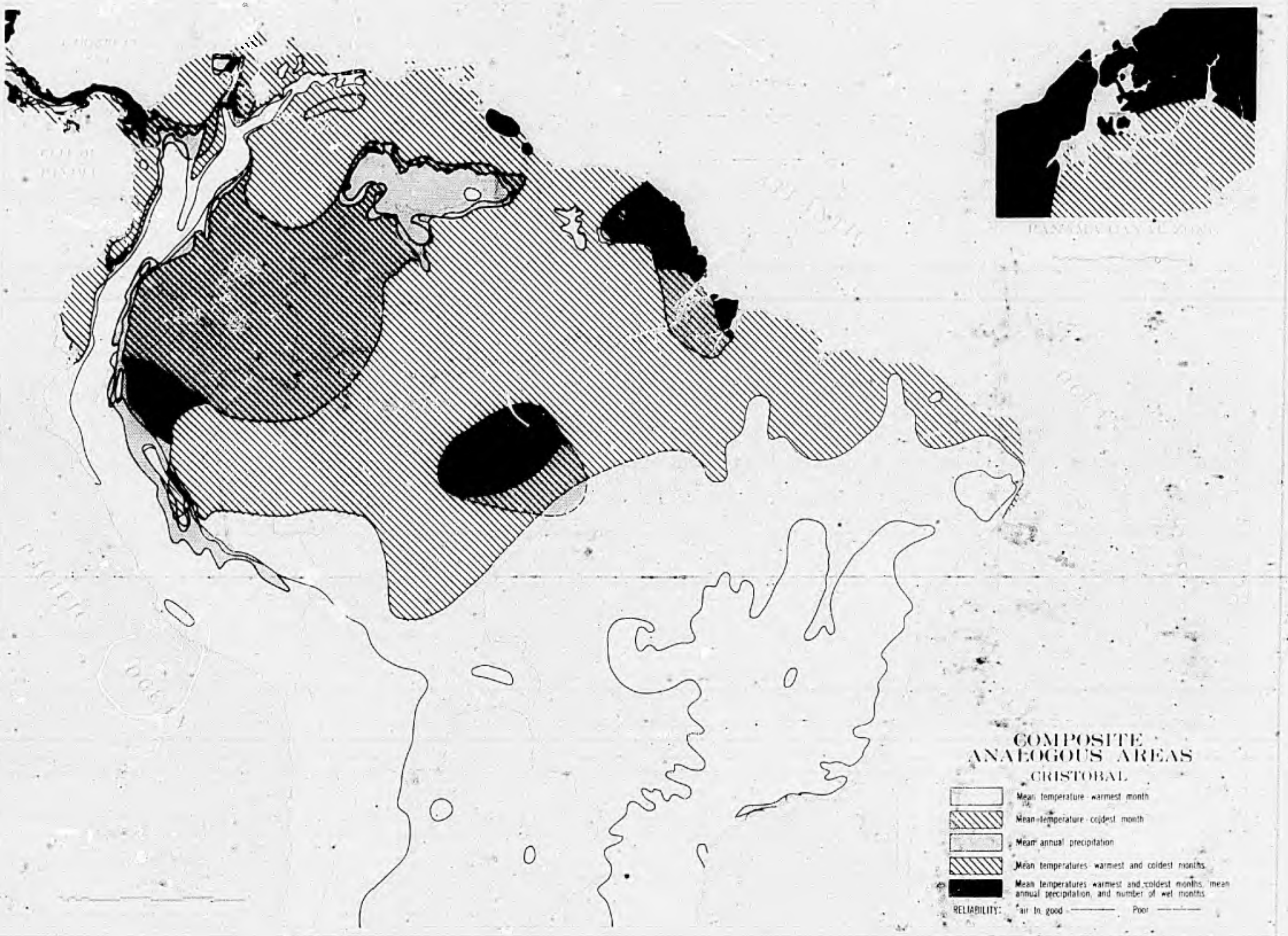

COMPOSITE
ANALOGOUS AREAS
CRISTOBAL
Mean temperature - warmest month
Mean temperature - coldest month
Mean annual precipitation
Mean temperatures - warmest and coldest months
Mean temperatures - warmest and coldest months, mean annual precipitation, and number of wet months
RELIABILITY: Fair to good ——— Poor ———

Figure 15